

AD-785 375

WEAPON SYSTEM COSTING METHODOLOGY FOR
AIRCRAFT AIRFRAMES AND BASIC STRUCTURES,
VOLUME IV. ESTIMATING TECHNIQUES
HANDBOOK

R. E. Kenyon

General Dynamics

Prepared for:

Air Force Flight Dynamics Laboratory

April 1974

DISTRIBUTED BY:

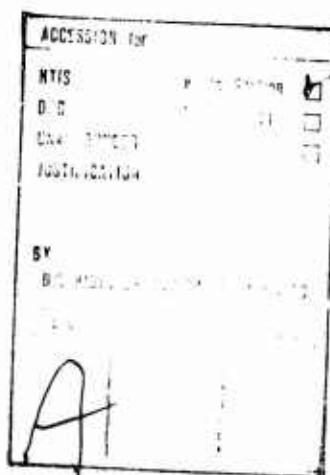


National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

**Best
Available
Copy**

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.



Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

AFFDL-TR-73-129-Vol. IV

**WEAPON SYSTEM COSTING METHODOLOGY
FOR AIRCRAFT AIRFRAMES AND
BASIC STRUCTURES**

VOLUME IV • ESTIMATING TECHNIQUES HANDBOOK

R.E. Kenyon

General Dynamics Convair Aerospace Division
Kearny Mesa Plant, San Diego Operation
5001 Kearny Villa Rd., San Diego, California 92138

FOREWORD

This report was prepared by the Convair Aerospace Division of General Dynamics, San Diego, California, under USAF Contract F33615-72-C-2083. The contract titled "Weapon System Costing Methodology for Aircraft Airframes and Basic Structures," was initiated under project 1368, "Advanced Structures for Military Aerospace Vehicles," Task 136802, "Structural Integration for Military Aerospace Vehicles." The work was administered under the direction of the Air Force Flight Dynamics Laboratory, Structures Division, Wright-Patterson Air Force Base, Ohio, under the direction of Mr. R. N. Mueller (AFFDL/FBS) as Project Engineer.

This report covers work conducted from July 1972 to September 1973 and was submitted by the author in October 1973, under General Dynamics Report CASD-AFS-73-001 as an Interim Technical Report. This report includes three additional volumes: Volume I, Cost Methods Research and Development; Volume II, Supporting Design Synthesis Programs; Volume IV, Estimating Techniques Handbook.

The principal author and project leader on this program is Mr. R. E. Kenyon, under the administration of Mr. G. E. Vail, Chief of Economic Analysis and Mr. A. Van Duren, Manager of Operations Research. Others who contributed to the studies and who contributed in the preparation of this volume include Messrs. J. L. Youngs, Economic Analysis; B. H. Oman and W. D. Honeycutt, Mass Properties; and Gary Clark, Design Programming.

This technical report has been reviewed and is approved.



KEITH I. COLLIER

Chief, Advanced Structures Branch
Structures Division
Air Force Flight Dynamics Laboratory

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE
1 JAN 73

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

secondary structure.

This volume provides a handbook as a guide to the trade study cost estimating technique. The function of the computer program is described. The program output format and the input data requirement and its organization are discussed and reference is provided to the cost estimating logic involved.

11 UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

*U.S. Government Printing Office: 1974 657-012/09

ABSTRACT

This report presents the interim results of a study aimed at extending cost estimating techniques developed and demonstrated under a previous contract. The previous study provided a trade study and a system study costing method for empennage elements. During the initial phase of the current study, these capabilities have been extended to include all aerodynamic surfaces: horizontal stabilizer, vertical stabilizer, canards treated as a stabilizer, and wings, including secondary structure.

This volume provides a handbook as a guide to the trade study cost estimating technique. The function of the computer program is described. The program output format and the input data requirement and its organization are discussed and reference is provided to the cost estimating logic involved.

TABLE OF CONTENTS

Section	Page
1 INTRODUCTION	1
2 TRADE STUDY COST ESTIMATING PROCEDURE	2
2.1 FLOW DIAGRAMS	2
2.2 COST OUTPUT SUMMARY	2
2.3 ESTIMATING LOGIC AND CER CROSS REFERENCE	2
2.4 COST MODEL COMPUTER PROGRAM	9
2.5 ORGANIZATION OF INPUTS	25
2.6 INPUT SOURCES	26
2.7 SUPPLEMENTAL ESTIMATING PROCEDURES	29
Appendix	
A INPUT DATA DECK LISTING	31
B SAV MATRIX EXAMPLE	43
C CONVERSIONS TO COMPUTER PROGRAM SYMBOLIC - NAMELIST VARIABLES	46
D CONVERSION TO COMPUTER PROGRAM SYMBOLIC - ESTIMATING COEFFICIENTS	52
E COMPLEXITY FACTOR TABLES	58
F LOOK-UP TABLES	65
REFERENCES	68

LIST OF FIGURES

Figure		Page
1	AFFDL Trade Study Cost Estimating Method	3
2	Basic Elements of the Trade Study Cost Estimating Method	4
3	Cost Output Format	5
4	First Unit Cost CER Cross Reference by Equation Number	7
5	Computer Program Deck Set-Up	10
6	Cost Model General Flow Diagram	15
7	SAV Matrix	17
8	Illustration of the Z - Card	19
9	Illustration of the R - Card	23
10	Input Variables Categorization	26

LIST OF TABLES

Table		Page
I	Complexity Factors, Rib Detail Fabrication	59
II	Complexity Factors, Rib Subassembly	60
III	Complexity Factors, Spar Detail Fabrication	61
IV	Complexity Factors, Spar Subassembly	62
V	Complexity Factors, Cover Detail Fabrication	63
VI	Complexity Factors, Cover Subassembly	64
VII	Engineering CER Coefficients	66
VIII	Tool Manufacturing Hours Input Table	67

SECTION I

INTRODUCTION

This volume provides the instructions necessary for making a cost estimate using the existing aerodynamic surfaces trade study cost estimating module. It gives a description of the method in terms of inputs, outputs, and estimating logic, shows the organization of inputs, describes and references input sources, and describes the computer program that is used. An example of a supplemental estimating procedure is also given. The flow diagram of the procedure shown in Volume I is repeated to provide an overall illustration of the method. The number of inputs required initially to set up a run is quite extensive. Generally, however, only a few input variations are required for subsequent trade study alternatives.

The emphasis in this discussion is on the user's point of view. The discussion relates to the mechanics of the procedure inasmuch as the estimating logic was discussed in Volume I.

SECTION 2

TRADE STUDY COST ESTIMATING PROCEDURE

2.1 FLOW DIAGRAMS

The trade study cost estimating method for aerodynamic surfaces is described in general terms in Figure 1. The final report will, of course, contain a description of the complete method. To illustrate the discussion, Figure 1 has been simplified as shown in Figure 2. Output is discussed first.

2.2 COST OUTPUT SUMMARY

The costs produced by this method are shown in Figure 3, which consists of four computer printout pages. Although not numbered, these will be referred to as pages 1 through 4 in the order in which they appear. Page 1 gives nonrecurring design and development costs. Page 2 gives detailed first unit cost, while Page 3 summarizes first unit cost by the six summary costs shown for each major component. Page 4 shows recurring costs by major component, which are obtained by projections of the summarized first unit costs.

2.3 ESTIMATING LOGIC AND CER CROSS REFERENCE

The cost estimating relationships that produce each of these estimates are given in Appendix B, Volume 1. Summary charts on pages B-3 and B-4 provide a correlation between the computer printout and the respective CERs for nonrecurring costs.

Page 2 of the computer printout has been rewritten as Figure 4 to show the CER reference, i.e., equation number, for each of the detailed elements of first unit cost. The chart on page B-72, Volume 1, correlates the recurring costs, printed out on Page 4, to the CERs for RDT&E and Procurement recurring production in Appendix B of that volume. The summary item, "Major Mate," on Page 3 is not yet covered pending completion of the fuselage CERs.

The above sets of CERs cover standard basic structure and thus may leave out special structural features such as full depth honeycomb, fuel tanks, sandwich skins, ducting, air induction and landing gear provisions that require supplemental estimating procedures. These procedures are discussed in Section 2.7.

The treatment of composite materials also presents problems. In general, estimating for composite material is handled in two ways reflecting the extent to which the composite material is used. The first involves the use of large amounts of composite

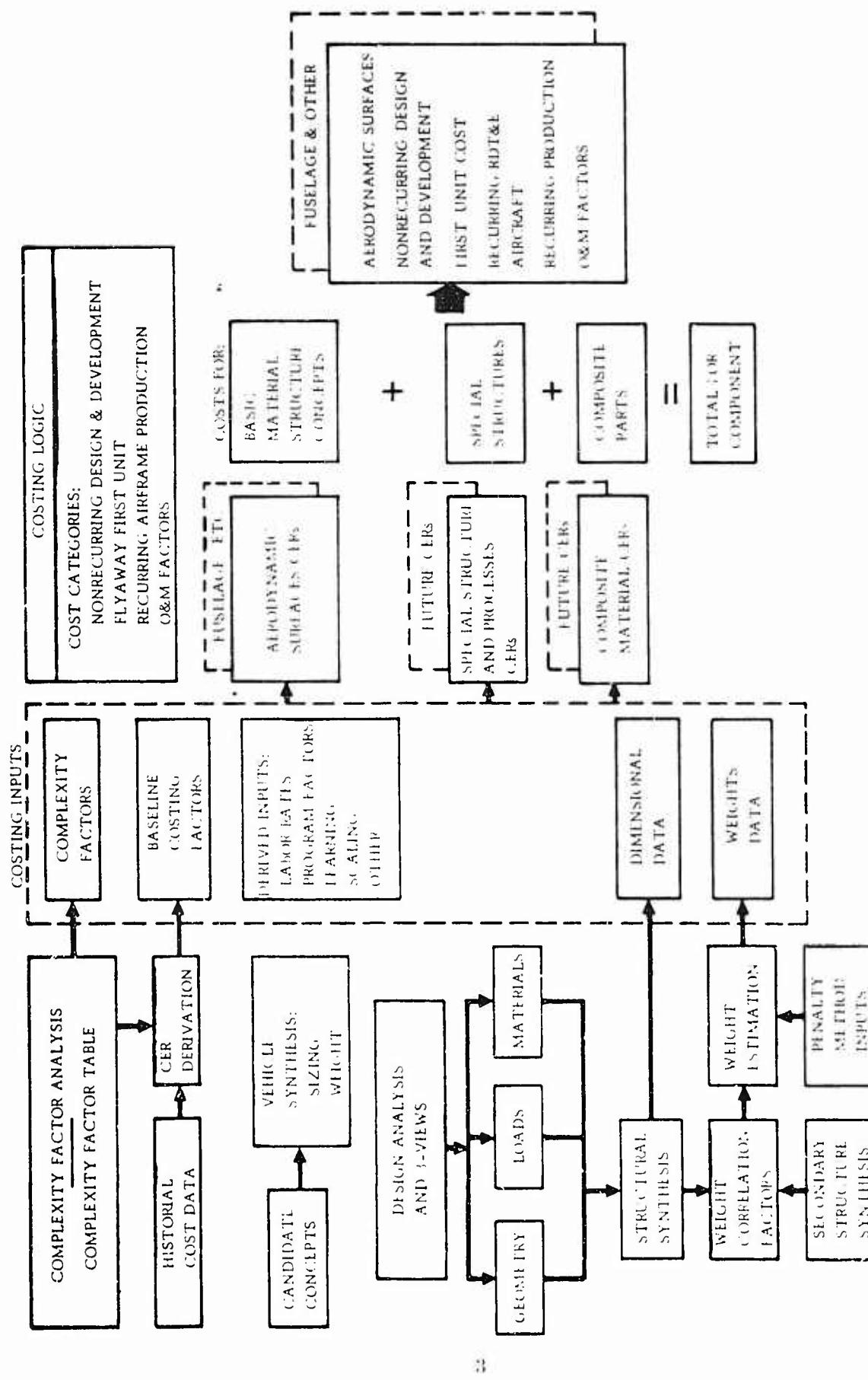


Figure 1. AFFDL Trade Study Cost Estimating Method

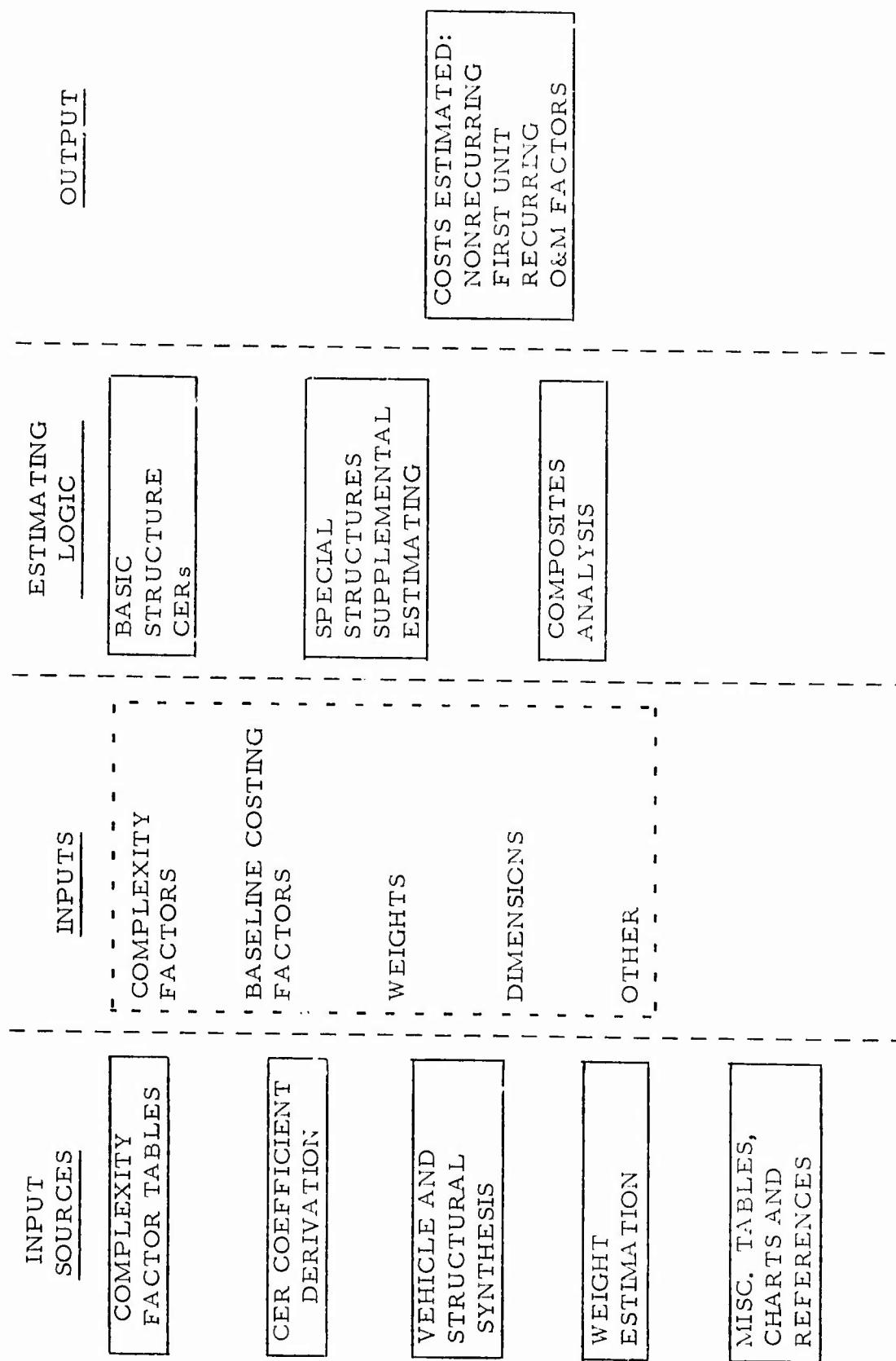


Figure 2. Basic Elements of the Trade Study Cost Estimating Method

AEROSPACE VEHICLE STRUCTURAL COSTS
NONRECURRING DESIGN AND DEVELOPMENT COSTS

12.56.12. 04/02/73

F-111A WING C-SA HSTAB F-111A VSTAB

EMPEN	WING	FUSE	NAE	SUM-	COLL
HAGI	LADE	LLF	HOURS	TOTAL	AR
HOURS	HOURS	HOURS	HOURS	HOURS	COSTS
BASIC STRUCT DESIGN ENGR HRS	75202	212150		289360	
CONFIGURATION DESIGN ENGR HRS				346332	8,6504
ENGINEERING MATERIAL					1,7302
TOTAL TRAD STUDY ENGR					10,3809

12.56.12. 04/02/73

F-111A WING C-SA HSTAB F-111A VSTAB

HORIZ	VERT	WING	FUSE	NAE	SUM-	COLL
ONTAL	ICAL	LADE	LLF	ELLE	TOTAL	AR
STAB	STAB	HOURS	HOURS	HOURS	HOURS	COSTS
BASIC TOOL MFG HOURS	13200	110500	1118000		1354500	
RATE TOOLING HRS HOURS					1352068	
TOTAL TOOL MFG HOURS					2710568	37.9479
BASIC TOOL FINING HOURS					611225	
RATE TOOL MFG HOURS					334016	
TOTAL TOOL FINING HOURS					944441	14.2401
NG DEVIL & PLANT HRS HRS					271056	4.9656
TOOLING MFG & OTHER DOLLARS						5,6711
MANUFACTURING SUPPORT DOLLARS						9,5159
QUALITY CONTROL HOURS					5A3637	9.9210

FIRST UNIT COST

12.56.12. 04/02/73

F-111A WING C-SA HSTAB F-111A VSTAB

WING	SUB-	WING	HSTAB	SUB-	HSTAB	SUB-	VSTAB
DEAS	ASSY	DEAS	DEAS	ASSY	DEAS	DEAS	DEAS
HOURS	HOURS	\$	HOURS	HOURS	\$	HOURS	\$
STRUCTURAL BOX							
RIBS	1063		1047	2163	856	6450	635
SPARS	7420		15106	4466	1106	10131	1971
COVERS	6193		27612	5341	1295	37237	1241
SUB-TOTAL	12656		6516	12688	3955	51824	3846
MAJOR ASSY		33385	33686		12182	11680	
SECONDARY STRUCTURE							
LEADING EDGE	1369	1162	1375	1479	1296	2373	1025
TRAILING EDGE	973	771	2040	912	724	2843	894
AILERONS							1557
FAIRINGS							
TIPS	603	602	789	1946	1460	2944	466
SPOILERS							369
FLAPS & FLAPRONS	4428	4043	6452		105	103	412
ATTACHM NT STRUCTURE					215	664	1366
ACCESS & OTHER DOORS							
AIR INJECTION							
HIGH LIFT DUCTING							
SLATS							
HINGE, SHACKLES, SEALS					625	525	2102
PIVOTS & FOLDS					533	533	5213
CENTER SECTION							
ELEVATORS					5494	5494	9267
BALANC WEIGHS					176	176	2994
RUDDER							
OTHER	4298	2579	6016				1642
SUB-TOTAL	11811	9134	16997	14201	13355	15952	3133
FINAL ASSY		14891	9046		6509	2437	1642

Figure 3. Cost Output Format.

12.56.12. 08/02/73
 F-111A WING C-5A HSTAB F-111A VSTAB

FUSLG OFAB HOURS	SUB- ASSY HOURS	FUSLG MATE \$	NACEL OFAB HOURS	SUB- ASSY HOURS	NACEL MATE \$
------------------------	-----------------------	---------------------	------------------------	-----------------------	---------------------

BASIC STRUCTURE

SUBTOTAL

MAJOR ASSEMBLY

SECONDARY STRUCTURE

SUBTOTAL

FINAL ASSEMBLY

12.56.12. 08/02/73

F-111A WING C-5A HSTAB F-111A VSTAB

SUMMARY	WING	WING	HSTAB	HSTAB	VSTAB	VSTAB	FUSLG	FUSLG	NACEL	NACEL	BASIC STRUCT HOURS	BASIC STRUCT \$
	HOURS	\$	HOURS	\$	HOURS	\$	HOURS	\$	HOURS	\$		
DETAIL FABRICATION	26467	362518	26489	376444	6979	97704					54335	816686
SUBASSEMBLY	9170	127432	17110	247340	2474	34676					23923	414126
MAJOR ASSEMBLY	33185	467193	17142	173744	3641	11533					49268	843471
FINAL ASSEMBLY	14891	147776	6509	91121	1042	15151					21686	363551
MATERIAL		185539		101488		28976						229103
TOTALS											158188	2442636

AEROSPACE VEHICLE STRUCTURAL COSTS
 RECURRING AIRFRAME PRODUCTION COSTS

12.56.12. 08/02/73
 F-111A WING C-5A HSTAB F-111A VSTAB

ROT+E (500)	MORIZ STAB	VERT STAB	WING	FUSE LAGE	NAC ELLE	HOURS	\$
SUSTAINING ENGRG SUSTAINING TOOLING MANUFACTURING							212799 5,3200
							1371117 20,5953
DETAIL FAB HOURS	217346	61512	216004				
ASSEMBLY HOURS	431446	46539	679281				
FINAL CONTL HOURS							
MATERIAL + OTHER	1632064	337315	1697209				

PROCUREMENT ARTICLES

SUSTAINING ENGRG SUSTAINING TOOLING MANUFACTURING							382357 9,5549
							2842836 30,6425
DETAIL FAB HOURS	1521956	395274	1385744				
ASSEMBLY HOURS	4746941	354472	7465454				
FINAL CONTL HOURS							
MATERIAL + OTHER	2943324	6,0325	30,1916				

Figure 3. Cost Output Format (Concluded).

First Unit Cost	Wing DFAB	Sub- Assy	Wing Mat'l	HSTAB DFAB	Sub- Assy	HSTAB Mat'l	VSTAB DFAB	Sub- Assy	VSTAB Mat'l
	Hours	Hours	\$	Hours	\$	Hours	\$	Hours	\$
Structural Box									
Ribs	1	10	127 128 129	2	11	152 153 154	3	12	173 174 175
Spars	4	13	130 131 132	5	14	155 156 157	6	15	176 177 178
Covers	7	16	133 134 135	8	17	158 159 160	9	18	179 180 181
Sub-Total Major Assembly	-	19-24	193	-	25-30	195	-	31-36	197
Secondary Structure	-7								
Leading Edge	40	41	136	72	73	161	96	97	182
Trailing Edge	42	43	137	74	75	162	98	99	183
Ailerons	44	45	138	-	-	-	-	-	-
Fairing	46	47	139	76	77	163	100	101	184
Tips	48	49	140	82	83	166	106	107	187
Spoilers	50	51	141	-	-	-	-	-	-
Flaps & Flaperons	52	53	142	-	-	-	-	-	-
Attachment Structure	54	55	143	88	89	169	112	113	190
Access Doors, Frames, etc.	56	57	144	86	87	168	110	111	189
Air Induction	58	59	145	-	-	-	-	-	-
High Lift Ducting	60	61	146	-	-	-	-	-	-
Slats	62	63	147	-	-	-	-	-	-
Hinges, Brackets & Seals	64	65	148	84	85	167	108	109	188
Pivots and Folds	66	67	149	90	91	170	114	115	191

Figure 4. First Unit Cost CER Cross Reference by Equation Number

First Unit Cost	Wing DFAB	Sub- Assy	Wing Mat'l	HSTAB DFAB	Sub- Assy	HSTAB Mat'l	VSTAB DFAB	Sub- Assy	VSTAB Mat'l
	Hours	Hours	\$	Hours	\$	Hours	\$	Hours	\$
Center Section	68	69	150	92	93	171	-	-	-
Elevators	-	-	-	78	79	164	-	-	-
Balance Weights	-	-	-	80	81	165	104	105	186
Rudder	-	-	-	-	-	-	102	103	185
Other	70	71	151	94	95	172	116	117	192
Sub-Total									
Final Assembly	-	$\begin{cases} 118 \\ 121 \\ 122 \end{cases}$	194	-	$\begin{cases} 119 \\ 123 \\ 124 \end{cases}$	196	-	$\begin{cases} 120 \\ 125 \\ 126 \end{cases}$	198

Figure 4. First Unit Cost CER Cross Reference by Equation Number (Concluded)

materials, in which case, assuming that structural elements such as ribs, spars, and covers are made completely of the composite material, estimates are made using the basic method. In this case, however, additional complexity factors comprising expanded complexity factor tables are required. The second situation occurs when only detailed parts are involved or when composite material is applied as a reinforcement to a conventional metallic part. In this case supplemental procedures are again required, and these are also discussed in Section 2.7.

Making a cost estimate for a standard type basic structure thus resolves itself into two main problems: (1) understanding and using the computer program, and (2) developing the input data required by the program. The cost model computer program is discussed in the next section. Sections 2.5 and 2.6 deal with the development of input data: the organization of inputs and the sources of these inputs.

2.4 COST MODEL COMPUTER PROGRAM

The aerodynamic surfaces module of the cost model computer program makes use of an existing general cost model program (designated as COSTC) taking advantage of certain features of that program. COSTC (P5514) is a data manager program written in FORTRAN IV for the CDC CYBER 72. Features include treating the cost estimating logic as a program input, handling the cost output as an array (called the SAV matrix) in a manner whereby it is both addressable and displayable, and providing a more flexible costing capability in relation to individual hardware elements.

Treating the estimating logic as a program input provides a simple means of modifying cost estimating relationships. These are accomplished simply by changing an input model card with a corresponding input variable change. Changes to estimating coefficients, which for example might result from additional analyses of historical cost data, can also be accomplished in this manner. Use of the SAV array printout provides for a display of intermediate computational results and permits the cost analyst to utilize computational results that are not typically available in a cost output format. Elements in this array may be used as terms in the cost estimating relationships.

A possible disadvantage in the use of the program is that it requires an understanding by the cost analyst of the additional coding involved. Also some understanding of the COSTC program and the SAV array is required.

The deck set-up for the complete cost program is shown in Figure 5. As can be seen, the major elements of the program are the program deck, the variable input, i.e., NAMELIST section, and the model cards input section. Control cards, title card and option card are also a part of the deck. Each of these parts are described below.

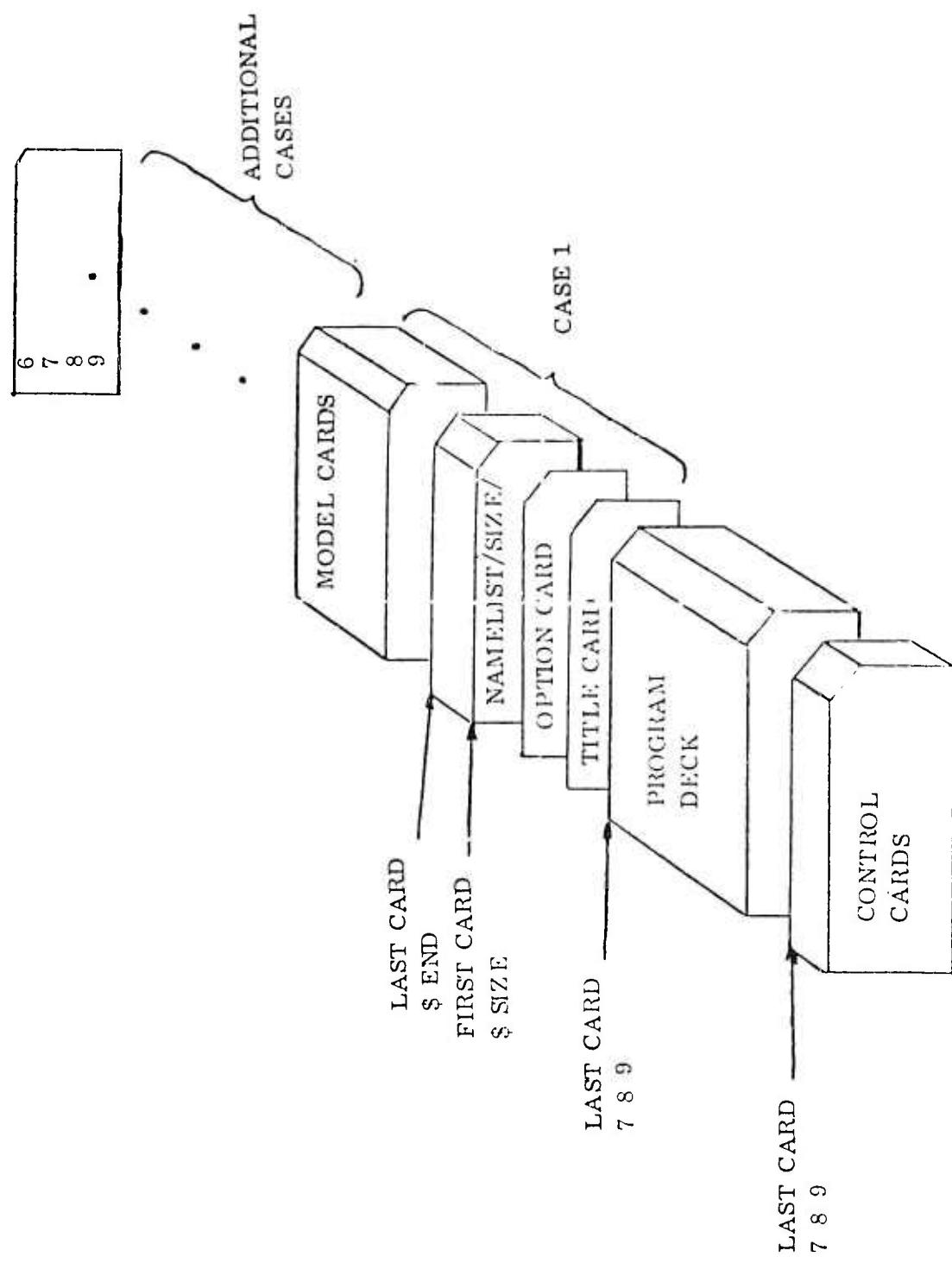


Figure 5. Computer Program Deck Set-Up.

The control cards entail an optional compiler usage. At Convair the program is compiled with the "RUN" compiler, but it may be compiled by either "RUN" or "FTN" compilers. The control cards for the use of a source deck with the "RUN" compiler are:

RUN.
LGO.
REWIND (TAPE 5)
COPYSBF (TAPE 5, OUTPUT)
EXIT.

The control cards for source decks under the "FTN" compiler are:

FTN.
LGO.
REWIND (TAPE 5)
COPYSBF (TAPE 5, OUTPUT)
EXIT.

The control cards for binary decks under either compiler are:

INPUT.
REWIND (TAPE 5)
COPYSBF (TAPE 5, OUTPUT)
EXIT.

The control cards for updating a routine, and executing the updated package with the "RUN" compiler are:

RUN (P)
COPYBR (INPUT, DISK, 20)
REWIND (LGO, DISK)
COPYL (DISK, LGO, NPL)
REWIND (NPL)
NPL.
REWIND (TAPE 5)

COPYSBF (TAPE 5, OUTPUT)

EXIT.

The program deck includes the following subroutines:

Driver: Program COSTC

The driver initialized all variables, reads in the input cards, checks program options, and executes various subroutines as "KEY" input cards are recognized.

Subroutine: GETPAR

This routine determines what is contained in each field of ten characters of the 'Z' and 'R' cards and returns this information.

Subroutine: SEARCH

This routine searches the variable name array and returns the subscript that corresponds to the name requested.

Subroutine: EXPR

This routine evaluates the expression between parenthesis used by the 'F' card.

Subroutine: CHECK

This routine checks to see if the next card is a continuation card.

Subroutine: TITLE

This routine is used to print titles.

Function: PWORD

This function selects nonblank characters from variable names and left adjusts them in PWORD.

Function: NUMBER

This function gets an integer from any vector between given locations.

Function: MRGCRD

This function checks for several of the "KEY" denoters for the merge option.

Subroutine: RECORD

This subroutine interrogates input cards for a line location in the SAV array.

Function: ICHKLIN

This function checks lines in the array SAV for zero values.

Subroutine: FINDINT

This subroutine finds the single integer up to 99 from an input field.

Subroutine: TMERGE

This subroutine merges new input cards with the current cost model.

Function: ROUND

This function rounds a real number to two decimal places.

Function: VALUE

This function finds the value of a term, parameter, or a coefficient.

Subroutine: EQEVAL

This subroutine is the driver for the 'F' cards of the model cards.

Function: IPACK

This function packs characters of input fields for input to subroutine GETPAR.

Subroutine: UNPAK

This subroutine puts data into a predetermined number of separate words for output.

Function: TERM

This function computes terms involving parameters and coefficients. Coefficients are input as real numbers and parameters are variable inputs or recalled sums.

Subroutine: READW

This subroutine reads input variables from the namelists, SIZE and CURVE.

After any set of control cards and following the program deck, the input cards follow. These are:

TITLE CARD

OPTION CARD

NAMELIST INPUT CARDS

MODEL CARDS

A general flow diagram of the input sequence is shown in Figure 6. A printout of a complete set of input cards is shown as Appendix A.

The Title card uses 80 columns of alphanumeric data to be printed as the main title. The Option card is composed as follows:

Column

1-5	CLEAR	If this word is punched in this field, the variables are set to 0 before reading the new variables.
	blank	If the field is blank, the variables used in the previous case are not cleared before reading new variables.
6-10	CARDS	If the model is going to be read from cards.
	TAPE2	If the model cards are either on Tape 2 for the first case only or the previous cost model information is to be reused.
	MERGE	If the model cards are either merged from card input and TAPE2 for the first case only or the previous model data is merged with revised cards thereafter.
11-15		Integer that specifies the maximum number of variables to be used by an element of the model.
16-20		Name of Element 1, i.e., Wing
21-25		Name of Element 2, i.e., Horizontal Stabilizer
26-30		... etc. . . .

Model cards are entered on tape, designated as TAPE 2, by appropriate request. The MERGE option provides for obtaining input from both TAPE and new input cards and is used for any change in input values or CERs for multicase runs.

When the MERGE option is being used, the program will assume that a baseline model has been previously stored on tape and that the cards contained in the Cost Model section of input are to be merged with the baseline model to produce and process an updated model. The following rules should be observed when merging:

- a. Z, R and F cards only can be merged.
- b. When replacing an element of the SAV matrix all the terms that make up that element should be replaced.
- c. Merge cards should be ordered monotonically increasing by line and column number.

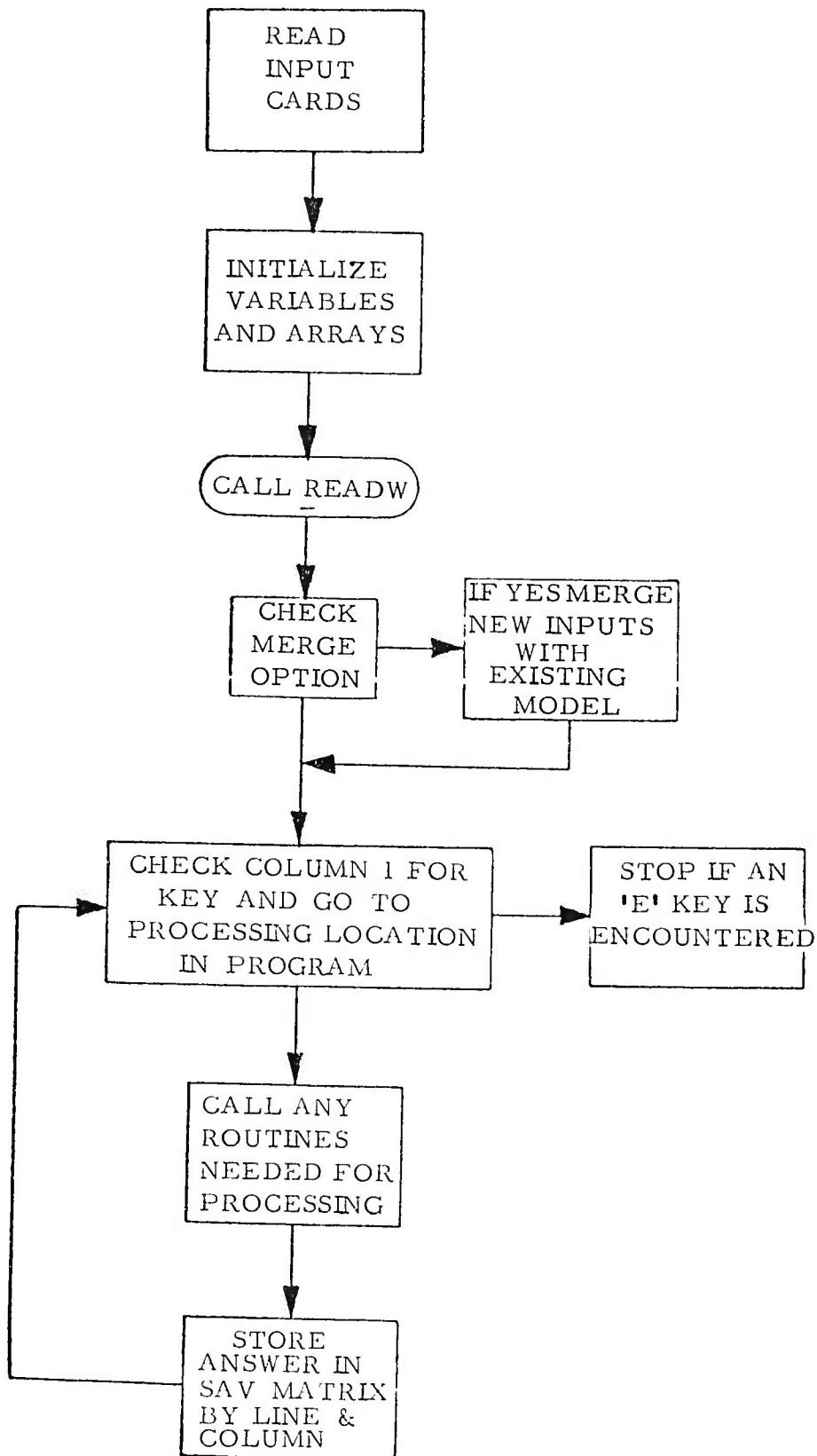


Figure 6. Cost Model General Flow Diagram.

- d. New columns may be inserted to a defined line in the baseline model. New lines may not be inserted.
- e. A combination of Z-cards may replace an R-card. The converse is not valid.

NAMELIST cards record the input variables. The NAMELIST identifier is SIZE. One set of variables in a SIZE block corresponds to an element of the model. As many SIZE blocks are read as are specified by the number of elements punched in the option card, and the inclusion or exclusion of an element is controlled by the option card. Sets of variables must then be furnished to correspond.

The first case should contain all the variables that are used by the model. For subsequent cases, only the variables that are to be changed are input. Variables are stored in a single dimensional array called PL. They are stored by elements and are printed out by element for each case run.

The costing program is built into a series of model cards where column 1 of each card is used as a "key" to determine the specific function of that card. The various types of cards are discussed below, following a discussion of the SAV matrix. The nature of this matrix and its relationship to the model cards help explain the function of the model cards.

The COSTC program provides a printed-out array of the results of the calculations directed by the model cards. This printout is called the SAV matrix. It is organized in lines and columns, which are numbered and addressable by the model cards. A value "stored" in any element of this matrix may be used as a term, and manipulated, by certain model cards. The SAV matrix is dimensioned by the driver program, COSTC. A general layout of the SAV matrix is shown in Figure 7. The number of rows in the matrix corresponds to the number of lines containing cost values that are to be printed out. It is limited only by the dimension statement and, in turn, core capacity. The current program is dimensioned for 500 lines and 13 columns. The number of columns in the matrix corresponds to the number of columns that may be printed out. The program presets the SAV matrix to zeroes before the execution of a run. Terms are computed and added to a specific location in the matrix addressed by line and column number by the operative model cards. As an example of the operation of the matrix and the correspondence to the model cards, reference is made to Appendix A, a listing of the input deck, and Appendix B, a sample SAV matrix.

In Appendix A, on the first page, an entry appears as follows:

F 5 7 W1 VTL* CF1 VTL + W2 VTL * CF2 VTL + W3 VTL* CF3 VTL

This is an "F" card as noted by the F in the first column. The SAV matrix line is 5 and the column is 7. In Appendix B, the SAV Matrix, on the first line, line 5, and

	COLUMNS												
	1	2	3	4	5	6	7	8	9	10	11	12	13
LINES:													
1												N	
THRU													
500													
NOTES:													
(1) The address for N is (1,3)													
(2) Column 13 is used only for summation of the values entered on a given line.													

Figure 7. SAV Matrix.

counting in 7 columns will be found recorded the results of this calculation (the sum of rib type weights and complexity factor products).

As another example of the relationship, Appendix A, on the second page, shows

$F\ 16\ 1\ ((5,3) + (6,3) + (7,3)) * .10 + (15,8) * 2.0.$

This translates as follows:

Enter on line 16, column 1, of the SAV matrix the sum of line 5, column 3, line 6, column 3, and line 7, column 3, multiplied by .10 and the value entered in line 15, column 8, multiplied by two. This program thus provides visibility of computations and provides a high degree of programming flexibility.

The functions of the model cards are described below, including the rules applicable to the use of each type of card. The cards are discussed in the order in which they appear in the printout in Appendix A, except that all of the input oriented cards are grouped together and discussed first. The complete list of card types in the order in which they appear in the model deck, is B-card; 1-card; 2-card; 3-card; F-card; blank-card; C-card; N-card; T-card; D-card; R-card; P-card; Z-card; L-card; and E-card. The input oriented cards are: F-card; R-card; Z-card. Of this group, the Z-card will be discussed first because it is the basic card form with the F- and R-card being special cases.

Z-Card

The Z-card is a general computational form that makes use of a specified equation form described with respect to the terms used in the equation and designated by a "term" code. The results of the computation are added in a specified line and column of the SAV matrix. The composition of the card is as follows:

Column

1	Z to designate Z-card
2-4	Line number of the SAV matrix
5-7	Column number of the SAV matrix
8-10	Designation of term code being used

The rest of the card, columns 11 thru 80 is divided into seven subfields of 10 columns each. These subfields contain the parameters and coefficients used in the selected term (i.e., equational form). Parameters and coefficients may be punched in any subfield as long as they are read in increasing order: C_1 should precede C_2 , and C_2 should precede C_3 , etc. Coefficients should contain a decimal point. If an E format is used, it should be right adjusted in the field. Parameters can be made of input variables, calculations recalled from the SAV matrix or the sum of subsequent lines in one column. This composition may be clarified by reference to an example from Appendix A. The first use of a Z-card appears on Page 41, and is illustrated in Figure 8. The letter Z designates the Z-card. The results of the calculation are to be entered on line 142, column 2, of the SAV matrix. The term code is 24, and its meaning is explained below. The integers 101 followed by 5 with intervening blanks serves to recall the calculation results stored in line 101, column 5 of the SAV matrix. The value 18, which is labeled N1 is a parameter for the quantity of RDT&E aircraft being considered and .74 is the applicable learning curve slope in decimal form.

Terms and their codes that are handled by COSTC are as follows. C_i denotes coefficients and P_i denotes parameters. Coefficients are input as real numbers. Parameters can be variables or recalled elements of the matrix or a sum of subsequent lines on a column of the matrix.

<u>CODE</u>	<u>TERM</u>
1	O
2	C_1
3	P_1
4	$C_1 P_1$

COLUMNS								
10	20	30	40	50	60	70	80	
Z142	2 24	101	5	18.	.74			
		N1	*		PC1	*		

*Not part of the Z-Card

Figure 8. Illustration of the Z-Card.

<u>CODE</u>	<u>TERM</u>
5	$C_1 C_2$
6	$C_1 C_2 P_1$
7	$C_1 P_1 C_2$
8	$C_1 C_2 C_3$
9	$C_1 C_2 C_3 P_1$
10	$C_1 C_2 P_1 C_3$
11	$C_1 (C_2 P_1) C_3$
12	$C_1 C_2 P_1 (P_2/P_3) C_3$

13 $C_1 C_2 C_3 C_4$
 14 $C_1 C_2 C_3 C_4$
 15 $C_1 C_2 C_3 P_1 C_4$
 16 $C_1 C_2 (C_3 P_1) C_4$
 17 $C_1 C_2 (P_1/C_3) C_4$
 18 $C_1 P_1 P_2$
 19 $C_1 P_1 P_2 P_4/P_3$
 20 $C_1 C_2 P_1/P_2$
 21 $C_1 C_2 P_1 P_2 C_3$
 22 $C_1 C_2 P_1 C_3 P_2 C_4$
 23 $C_1 C_2 (P_1/P_2) C_3$

24 If $P_2 \leq 20$ $P_1 \sum_{i=1}^{P_2} i^x$
 If $P_2 > 20$ $P_1 \left[\frac{P_2^{x+1} - 1}{x+1} + \frac{P_2^x + 1}{2} \right]$

where $x = \frac{\ln C_1}{\ln 2}$

25 $P_1(P_2)^{x+1}$

where $x = \frac{\ln C_1}{\ln 2}$

26 $SAV(LINE, COL) = SAV(LINE, COL) \prod_{i=1}^I C_i \prod_{j=1}^J P_j$

where $I =$ number of coefficients.

$J =$ number of parameters.

27 $C_1 C_2 (P_1/P_2) C_3 P_3 C_4$

$$28 \quad P_1 \frac{(x_1 - x_2)}{P_2} \sum_{i=P_2+1}^{P_2+P_3} n^{x_2}$$

29 Same as Term 24 for $P_2 > 20$ except that P_2 can be any value.

Term code 24 signifies an equation of the following form,

$$\text{TERM} = P_1 \sum_{i=1}^{P_2} i^x$$

where

TERM = results of the calculation that is entered on line 142, column 2, of the SAV matrix

$P_1 = (101, 5)$ = first unit cost recalled from line 101, column 5 of the SAV matrix

$P_2 = N_1$ = the production quantity considered

$x = PC_1$ = the learning curve percentage in decimal form

(The entries N_1 and PC_1 as shown in Appendix A are not part of the Z-card. They are obtained by means of a "blank-card.")

When punching parameters in the subfields, the following rules must be observed.

a. If the parameter is a variable input the input name should be punched in the first 6 columns of the subfield. The last 4 columns are used for the element name. For example:

CF 1 WNG refers to a value of a particular complexity factor when the element being estimated is the wing.

b. Recalled calculations are designated by punching in the subfield a pair of integers separated by blanks. They may be punched in any columns of the subfield. The first integer is the line number and the second integer is the column number of the recalled calculation.

- c. Sum of subsequent lines are specified by punching three integers separated by blanks in the subfield. The first integer is the number of subsequent lines to be summed. The second integer is the starting line number. The third integer is the column number. This parameter is used for totalling.
- d. If the recalled calculation belongs to the present line being computed, only the column number need be punched in the subfield. The program will use the line number specified in column 2-4 of this card. The column number may be punched anywhere in the subfield.
- e. Parameters can be made of the sum of several parameters when they are specified in the subfields. This does not apply to terms 12, 18, 19, 20, 21 and 22, where each P_i is made up of only one parameter.
- f. A recalled calculation is subtracted if the line number of the recalled matrix element is punched as a negative integer.

The program stops processing a Z-card when a blank subfield is encountered. A Z-card may have one continuation card when 7 subfields are not enough to describe the term. For the continuation card, punch a "Z" in column 1, a "C" in column 2, and use the 7 subfields starting in column 11.

F-Card

The F-card is a generalization of the Z-card which permits writing the estimating formula in a Fortran-compatible format rather than specifying a term code. The card format is:

Column

- 1 F to designate F-card.
- 2-4 Line number of the SAV matrix
- 5-7 Column number of the SAV matrix
- 11-80 Formula.

F-card continuation is permissible for one additional card. The continuation card format is:

Column

- 1 F
- 2 C to designate a continuation card.
- 11-80 Remainder of formula.

Most of the cost model logic is contained on F-cards. R-cards are used as a convenience in some cases and Z-cards are used for formula complications involving equational forms that cannot be handled by the F-card as related to the COSTC driver program.

R-Card

This card is again a special case of the Z-card. The analyst should be familiar with the Z-card before using this card. In the application for this model, it is used to transfer data within the SAV matrix. The discussion can be illustrated by the R-card entry at the top of page 35. This example, shown in Figure 9, is interpreted as follows:

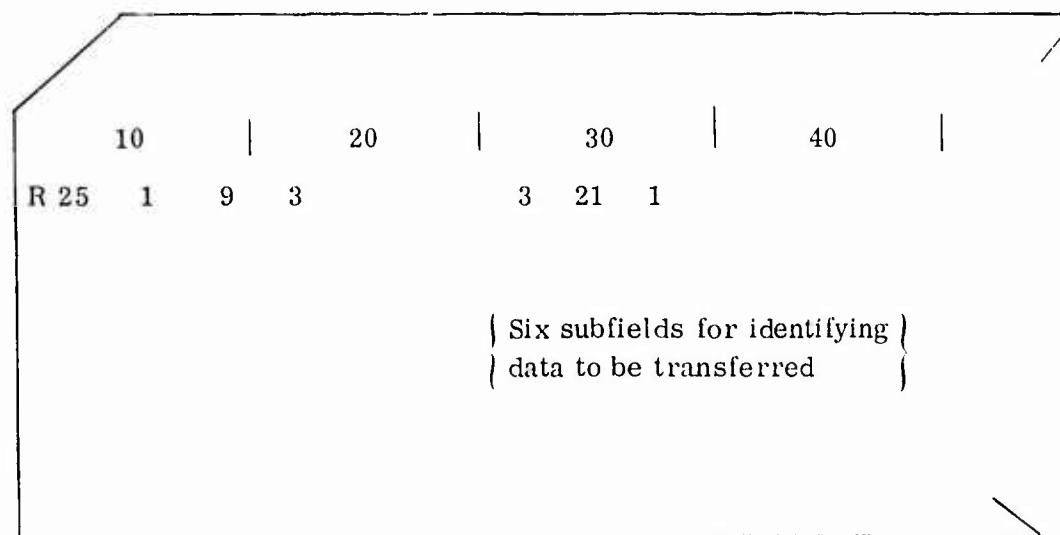


Figure 9. Illustration of the R-Card.

Column

- 1 R designated R-card.
- 2-4 Line number for SAV matrix recording
- 5-7 Beginning column number for recording.
- 8-10 Ending Column number for recording
- 11-13 Term code selected.
- 21-80 Divided into six subfields of 10 columns each.

Thus three lines starting with line 21, (i.e., lines 21, 22, and 23) and starting with column 1 and progressing by column are to be transferred to line 25, starting with column 1 and continuing thru a total of nine columns. That is the SAV matrix entries in column 1, lines 21, 22, and 23 are summed and added to column 1, line 25. Entries in column 2, lines 21, 22, and 23 are summed and added to column 2, line 25 and so forth for nine columns. The term code selected, Code 3, indicates that no other operations are involved. It can be seen that this application is simply a summing and recording operation.

In general the R-card is used when the coefficients and term code remain constant from column to column throughout a time. An entire line can be calculated with the R-card when the parameter is the only factor that varies, either as a function of the column or the element. As in the Z-card a continuation card may be used when six subfields are not enough to describe the terms.

B-Card

The B-card defines the format used in converting values from the SAV array to the print line. If no B-card has been read, a default format of (12(3X, E7. 1)) will be used. A format will remain in effect until another B-card is read with a new format. The format may appear anywhere in cols. 11-80 of the B-card, and should follow standard FORTRAN IV form. (The word FORMAT is not used.) The format may include scaling factors such as -6P to convert values stored in dollars to print values in \$millions. The format must be defined in groups of 10 characters, with the first 3 characters of each group skipped. This is because the output fields are in groups of ten and otherwise would not line up properly under output headings. There must be at least as many groups as there are columns to be printed. Some examples are:

(3X, -6PF7. 1)	gives 1 column in \$million up to 99999. 9
(12(3X, F7. 0))	gives up to 12 columns in units up to 9999999
(3X, -6PF7. 3, 11(3X, F7. 0))	Gives one column in \$million up to 999. 999 and up to 11 columns in \$million up to 99999. 9

1-Card

Contains the first line of column titles. Read in fields of 5 columns starting in column 11.

2-Card

Contains the second line of column titles. Read with the same format as above

3-Card

Contains the third line for column titles. Read as indicated above.

blank-Card

This card will be ignored in the output printout but will be printed in the model card input printout.

C-Card

Comment card. Columns 3 through 80 will be printed.

N-Card

This card contains information related to column printing.

Column

1 N designates N-card.

2-3 Number of columns that will be printed. The maximum number is 12.

4 When a "P" is punched in this column, the program will sum the columns on each line and print it as one additional column. When 12 columns are already being printed, the 13th column will not be printed for lack of space.

11-80 Any alphanumeric characters used for secondary title.

T-Card

Print titles.

D-Card

This will cause the printing of the line just computed by the preceding Z-cards or R-cards. Columns 3-38 of this card will be printed as the title for that line

P-Card

Ejects a page.

L-Card

List PL weight matrix and SAV matrix

E-Card

End of case. Will send program to read another title card.

2.5 ORGANIZATION OF INPUTS

In the procedure presently used, inputs to the model cards deck are transmitted from the cost analyst to the computer programmer in a format that coincides with the CER symbology as shown in Appendix B, Volume 1. The format for this transmittal is illustrated in Appendix C, Volume 1. The computer programmer adapts these inputs to the computer symbology using the dictionary for conversion to computer program symbology included in Appendix B. In the final program this conversion list will be eliminated by modifying the CER symbology to use computer program symbology.

The above inputs are categorized from two standpoints as shown in Figure 10:

- a. The section of the model cards deck affected.
- b. The source of the input.

As shown in Figure 10, NAMELIST variables are obtained from four sources: the APAS program, the secondary structure synthesis, the complexity factor tables, and "Other" sources. Both weight data and dimensional data are involved. Non-namelist variables appear within individual F-cards as labeled in Appendix A. Namelist variables are subject to change with each study case, whereas the F-card variables do not usually change from case to case and frequently change only as the result of additional cost research. Input sources are described in the next section. Revisions can be made in these categories, if need dictates, simply by changing the F-card to indicate the variable name rather than a constant and by including the variable in NAMELIST. It can be seen from this comment that the distinction is merely one of convenience describing the type of input card manipulation required for a new input.

The diagram illustrates the categorization of input variables. On the left, an arrow points from 'Model Cards Location' to a vertical stack of three categories: 'Namelist/Sizer', 'F-Cards', and 'Other'. To the right of this stack is a table with 'Input Source' as the header row. The table has five rows: 'APAS Program', 'Secondary Structure Synthesis (including penalty wt. method)', 'Complexity Factor Tables', 'CER Coefficient Derivation Charts', and 'Other'. The 'Namelist/Sizer' column contains 'x' for APAS, Secondary Structure, Complexity Factor Tables, and 'Other', and a dash for CER Charts. The 'F-Cards' column contains a dash for APAS, Secondary Structure, Complexity Factor Tables, and 'x' for CER Charts.

Input Source	Namelist/Sizer	F-Cards
APAS Program	x	-
Secondary Structure Synthesis (including penalty wt. method)	x	-
Complexity Factor Tables	x	-
CER Coefficient Derivation Charts	-	x
Other	x	x

Figure 10. Input Variables Categorization.

2.6 INPUT SOURCES

The NAMELIST variables are listed in Appendix C with the source indicated. Appendix D similarly lists F-card variables with their source.

Runs of the APAS program and the secondary structure synthesis program are required to support a given cost model run. These supporting programs are described in Column II. A tape transfer of data from these programs will be provided after the fuselage module is completed.

The presently available complexity factor tables are presented in Appendix E. These are referenced by the NAMELIST variables in Appendix C.

The input source called "Other" is a grouping of given values and lookup tables as referenced below and included in Appendix F.

Organization of "Other" Inputs

	<u>Input Symbol</u>	<u>How Obtained</u>
EH	Engineering hours at $W = 1$ lb.	Table VII - Appendix F
B	Scaling of hours to AMPR weight	From design hour plots
F_1	Factor for configuration design engineering	Average value is .14
ECLR	Engineering composite labor rate	An average figure subject to manufacturer's experience
F_2	Engineering material as % of engineering labor cost	Average value is 10%
C	Scaling of tooling hours by AMPR weight	Value is 1
TMF	Tooling complexity factor by component	Table VIII - Appendix F
T	Assumed monthly production weight	To be obtained from program plan data
B	Tool production rate scaling exponent	Average value is 0.3
F_3	Percentage factor of basic tool hours manufacturing	Average value is 40%
F_4	Percentage factor of rate tool manufacturing hours	Average value is 20%

	<u>Input Symbol</u>	<u>How Obtained</u>
F_5	Percentage factor of mfg. devel. and plant engrg. hours	Average value is 2% based on judgement
THC	Tool manufacturing labor cost per hour	An average figure based on manufacturer's experience
TEC	Tool engineering labor cost per hour	An average figure based on manufacturer's experience
TDC	Composite labor cost for mfg. devel. and plant engrg.	An average figure based on manufacturer's experience
F_6	Tooling material support factor (\$/hr)	Average value is \$1.00 per tool manufacturing hour based on F-106, F-102, B-58 and F-111 experience (\$1970)
F_7	Development support factor, % of E_c	From RAND studies, Reference 1
F_8	Percentage of engineering direct labor hours	Average value is 1% based on judgment
F_9	Percentage of tool manufacturing direct labor hours	Average value is 6% based on judgment
RQC	Composite quality control labor rate	An average figure based on manufacturer's experience
N_1	Number of RDT&E airframes	To be obtained from program plan data
ES	Scaling of sustaining engrg. with quantity	An average figure subject to manufacturer's experience
TU	Scaling of sustaining tooling with quantity	An average figure subject to manufacturer's experience
RT	Composite tooling labor rate	An average figure subject to manufacturer's experience
PC_1	Learning curve decimal fraction for detailed fab. hours	An average figure subject to manufacturer's experience
PC_2	Learning curve decimal fraction for assembly hours	An average figure subject to manufacturer's experience
	Mfg. Labor Rate	An average figure subject to manufacturer's experience
F_{10}	Ratio between quality control and manufacturing hours	An average figure subject to manufacturer's experience

	<u>Input Symbol</u>	<u>How Obtained</u>
N_2	Number of RDT&E and procurement production quantities	To be obtained from program plan data
F_{11}	Ratio between quality control and manufacturing hours for procurement production	An average figure subject to manufacturer's experience
HSA1	Assembly hours per unit weight	Value is .1
HSA2	Average assembly hours per subassembly	Value is 2
Q	Quantity scaling factor	Value is .95
R	Sizing scaling exponent	Value is .95
CSO	Center section operator	Value is 1 if no center section, 2 if there is a center section
R1	Size scaling parameter	Value is .95
U	Rework Factor	Judgment factor

Supporting tables and charts will be provided as they are completed and will be incorporated in the Final Report.

The principal source of F-card variables is the continuing analysis of historical cost data embodied in the series of scatter diagrams used originally to derive hours per pound and scaling exponents; i. e., the so-called CER coefficients. The derivation of these is described in Volume I, page 59. Currently available data is provided in Volume III.

2.7 SUPPLEMENTAL ESTIMATING PROCEDURES

Two examples of supplemental estimating procedures have been developed to date in this study, one for full depth honeycomb construction and the second for the ADP advanced fighter wing box. The first is discussed on page 70 and the second on page 51 of Volume 1.

The method is to use a set of supplementary equations in addition to the basic set of equations for metal structures already described. This approach is based on the idea that the cost of the hardware described by inputs to the basic equations is predicted properly, but when a substantially unique item is involved in part or in all of

the structure, the additional costs must be predicted, and the use of supplementary equations is required. The basic equations predict an incomplete structural cost that must be augmented by the unique-item-peculiar costs predicted by the supplementary equations. The set of equations used covers the following items:

a. Added Structural Box Cost:

Detailed fabrication hours.

Material cost.

Assembly costs.

b. Added Cost to Other Structure:

Labor hours.

Material.

Multiple equations are used in some cases. In each case costs are additive to those obtained from the basic equation set.

Typical items of structure that would be investigated in this way are:

- a. Fuel tanks.
- b. Sandwich skins.
- c. Ducting.
- d. Air induction.
- e. Landing gear provisioning.
- f. Full depth honeycomb.
- g. Adhesive bonding.

In the case of fuel tanks, an equation is needed to estimate the cost of those portions of the fuel tank that double as basic structure but that would not be required if fuel tanks were not located within the wing. Sandwich skins, upon determination of suitable factors, can be handled in a manner analogous to honeycomb core. Ducting would be separately costed but as a part of the subsystem with which it is associated: propulsion, flight control, environmental control, etc. Wing-mounted air induction interacts with the basic structure and must be analyzed in terms of the additional structural complexity that it introduces. A wing-mounted landing gear is treated as a penalty reflected as added cost to the basic structure. Estimating equations and the supporting estimating factors must be developed to support the above techniques.

APPENDIX A
INPUT DATA DECK LISTING -
NAMELISTS AND MODEL CARDS

F-111A VSTAR
CARUS 159WNG HTL VIL

Reproduced from
best available copy.

SIZE
END
SIZE
END
SIZE

w1=43.0, wCF1=99, wT=43.0, w4=101.0, wCF4=1.0, wT1=101.0, wT=313.1, CF7=2.40,
 wT2=313.1, CM1=0.0, CM4=0.0, CM7=0.0, CN=2.0, RN=5.0, SNE=2.0, SPL=21.0,
 RPE=9.0, IS4=10, RT1=1.0, RT2=1.0, wD3=0.0, CB1=1.0, wD1=78.7, CC1=1.0,
 CB3=1.0, wD3=139.7, CB3=1.0, CB5=1.0, wD5=21.3, CC5=1.0, WRRP=5.6, CS0=0.0,
 FSL=11.0, LVL=3.0, RSL=4.0, TS=1.0, FF3=1.0, CM8=1.0, AS2=313.0, RMC1=18.0,
 SF1=2.5, RMC4=18.0, SF4=5.3, RMC7=18.0, SF7=4.5, RMC10=18.0, SF10=3.0,
 RT1=10.0, SF11=3.0, RMC12=10.0, SF12=3.0, RMC13=10.0, SF13=3.0, RMC14=18.0,
 SF14=3.0, RT17=10.0, SF17=3.0, RMC18=10.0, SF18=3.0, RMC22=18.0, SF22=3.0,
 RMC23=10.0, SF23=3.0, RMC25=10.0, SF25=3.0, FM1=1.5, FM2=2.0,
 LHE=0.0, w1=7.1.2, RT=133.0, TAMPH=76.1.2

ر. ا. عاد

1 WING SKIN WING HSTARSHIR- HSTARVSTARSUB- VSTAR
 2 DFAB ASSY MATL DFAB ASSY MATL DFAB ASSY MATL
 3 HOURSHOURS \$ HOURSHOURS \$ HOURSHOURS \$
 F 5 1 W1 WNG*CF1 WNG+W2 WNG*CF2 WNG+W3 WNG*CF3 WNG
 F 5 4 W1 HTL*CF1 HTL+W2 HTL*CF2 HTL+W3 HTL*CF3 HTL
 F 5 7 W1 VTL*CF1 VTL+W2 VTL*CF2 VTL+W3 VTL*CF3 VTL
 (SUM OF K1B TYPE WEIGHT*COMPLEXITY FACTOR PRODUCTS)
 F 5 3 W1 WNG+W2 WNG+W3 WNG
 F 5 6 W1 HTL+W2 HTL+W3 HTL
 F 5 9 W1 VTL+W2 VTL+W3 VTL
 (SUM OF K1B TYPE WEIGHTS)
 F 6 1 W4 WNG*CF4 WNG+W5 WNG*CF5 WNG+W6 WNG*CF6 WNG
 F 6 4 W4 HTL*CF4 HTL+W5 HTL*CF5 HTL+W6 HTL*CF6 HTL
 F 6 7 W4 VTL*CF4 VTL+W5 VTL*CF5 VTL+W6 VTL*CF6 VTL
 (SUM OF SPAR TYPE WEIGHT*COMPLEXITY FACTOR PRODUCTS)
 F 6 3 W4 WNG+W5 WNG+W6 WNG
 F 6 6 W4 HTL+W5 HTL+W6 HTL
 F 6 9 W4 VTL+W5 VTL+W6 VTL
 (SUM OF SPAR TYPE WEIGHTS)
 F 7 1 W7 WNG*CF7 WNG+W8 WNG*CF8 WNG+W9 WNG*CF9 WNG
 F 7 4 W7 HTL*CF7 HTL+W8 HTL*CF8 HTL+W9 HTL*CF9 HTL
 F 7 7 W7 VTL*CF7 VTL+W8 VTL*CF8 VTL+W9 VTL*CF9 VTL
 (SUM OF COVER TYPE WEIGHT*COMPLEXITY FACTOR PRODUCTS)
 F 7 3 W7 WNG+W8 WNG+W9 WNG
 F 7 6 W7 HTL+W8 HTL+W9 HTL
 F 7 9 W7 VTL+W8 VTL+W9 VTL
 (SUM OF COVER TYPE WEIGHTS)
 F 8 1 TS4 WNG*Z0.0 / .04
 F 8 4 TS4 HTL*Z0.0 / .04
 F 8 7 TS4 VTL*Z0.0 / .04
 F 8 3 TS7 WNG*Z0.0 / .04
 F 8 6 TS7 HTL*Z0.0 / .04
 F 8 9 TS7 VTL*Z0.0 / .04
 (JOINT THICKNESS RATIO... 2.4SKIN THICKNESS / .04)
 F 9 2 W1 WNG*CM1 WNG+W2 WNG*CM2 WNG+W3 WNG*CM3 WNG
 F 9 5 W1 HTL*CM1 HTL+W2 HTL*CM2 HTL+W3 HTL*CM3 HTL
 F 9 8 W1 VTL*CM1 VTL+W2 VTL*CM2 VTL+W3 VTL*CM3 VTL
 (SUM K1B WEIGHT *COMPLEXITY FACTORS-SUBASSEMBLY)
 F 10 2 W4 WNG*CM4 WNG+W5 WNG*CM5 WNG+W6 WNG*CM6 WNG
 F 10 5 W4 HTL*CM4 HTL+W5 HTL*CM5 HTL+W6 HTL*CM6 HTL
 F 10 8 W4 VTL*CM4 VTL+W5 VTL*CM5 VTL+W6 VTL*CM6 VTL
 (SUM SPAR WEIGHT *COMPLEXITY FACTORS-SUBASSEMBLY)

F 11 2 .67 * 0.0007 * 0.0007 * WING*CM2 * WING
 F 11 3 .67 * HTL*CM2 * HTL*SF2 * HTL*CM3 * HTL
 F 11 6 .67 * VTL*CM2 * VTL*SF2 * VTL*CM3 * VTL*CM4 * VTL
 (SFC COVERS WINGHT + COMPLEXITY FACTORS - SUBASSEMBLY)
 F 12 3 .67 * WING*SF2 * WING*SF3 * WING*CM2 * WING*SF3 * WNG
 F 12 6 .67 * WING*SF2 * WING*SF3 * WING*CM2 * WING*SF6 * WNG
 F 12 9 .67 * WING*SF2 * WING*SF3 * WING*SF8 * WING*SF9 * WNG
 (TRIM, SPARE, COVER COST FOR WING TYPES 2+3)
 F 13 3 .67 * HTL*CM2 * HTL*SF2 * HTL*W3 * HTL*CM3 * HTL*SF3 * HTL
 F 13 6 .67 * HTL*CM5 * HTL*SF5 * HTL*W6 * HTL*CM6 * HTL*SF6 * HTL
 F 13 9 .67 * HTL*CM8 * HTL*SF8 * HTL*W9 * HTL*CM9 * HTL*SF9 * HTL
 (TRIM, SPARE, COVER COST FOR HTL TYPES 2+3)
 F 14 3 .67 * VTL*CM2 * VTL*SF2 * VTL*W3 * VTL*CM3 * VTL*SF3 * VTL
 F 14 6 .67 * VTL*CM5 * VTL*SF5 * VTL*W6 * VTL*CM6 * VTL*SF6 * VTL
 F 14 9 .67 * VTL*CM8 * VTL*SF8 * VTL*W9 * VTL*CM9 * VTL*SF9 * VTL
 (TRIM, SPARE, COVER COST FOR VTL TYPES 2+3)
 F 15 1 KP * WNG**.95 * SNE * WNG**.95 * (SNE WNG+SNI WNG)**.95
 F 15 4 KP * HTL**.95 * SNE * HTL**.95 * (SNE HTL+SNI HTL)**.95
 F 15 7 10 * VTL**.95 * SNE * VTL**.95 * (SNE VTL+SNI VTL)**.95
 (WNG+SNE+SNI) * (HTL+SNE+SNI) * (VTL+SNE+SNI) * 10 = P A R T A
 F 15 8 2.0 * ((C1 * WNG + KP * WNG + SNE WNG + VTL WNG) **.95)
 F 15 9 2.0 * ((C1 * HTL + KP * HTL + SNE HTL + VTL HTL) **.95)
 F 15 10 2.0 * ((C1 * VTL + KP * VTL + SNE VTL + VTL VTL) **.95)
 (WNG+SNE+SNI) * 10 = P A R T B
 F 16 1 ((5*3)+(5*3)+(7*3)) * .10 + (15*8) * 2.0
 WNG*HAS1+PART B * 2.0 (TRANSPORTATION + POSITIONING)
 F 16 2 (SPL WNG + KP WNG) * .210 * (8*1) * 2.0
 (SPL+KP) * HTL*TJ4*2.0 (PANEL FIT + TRIM)
 F 16 3 (15*1) * 1.230 * 2.0
 PART A * HTL*2.0 (ASSY CLAMP + LAYOUT)
 F 16 4 (15*1) * .557 * (8*1) * 2.0
 PART A * HTL*TJ4*2.0 (HOLE DRILLING)
 F 16 5 (15*1) * .810 * (8*1) * FF1 WNG * 2.0
 PART A * HTL*TJ4*FF1*2.0 (FINISH OPERATIONS)
 F 16 6 (15*1) * .970 * (8*1) * FF2 WNG * 2.0
 PART A * HTL*TJ4*FF2*2.0 (FASTENER INSTALLATION)
 F 16 7 (15*1)+(16*2)+(16*3)+(16*4)+(16*5)+(16*6) * .68 * FM1 WNG
 TOTAL ASSY LABOR HOURS * AMF1*FM1
 (BOX ASSEMBLY WING)
 F 17 1 ((5*6)+(5*6)+(7*6)) * .10 + (15*9) * 2.0
 WNG*HAS1+PART B * 2.0 (TRANSPORTATION + POSITIONING)
 F 17 2 (SPL HTL + KP HTL) * .210 * (8*4) * 2.0
 (SPL+KP) * HTL*TJ4*2.0 (PANEL FIT + TRIM)
 F 17 3 (15*4) * 1.230 * 2.0
 PART A * HTL*2.0 (ASSY CLAMP + LAYOUT)
 F 17 4 (15*4) * .557 * (8*4) * 2.0
 PART A * HTL*TJ4*2.0 (HOLE DRILLING)
 F 17 5 (15*4) * .810 * (8*4) * FF1 HTL * 2.0
 PART A * HTL*TJ4*FF1*2.0 (FINISH OPERATIONS)
 F 17 6 (15*4) * .970 * (8*4) * FF2 HTL * 2.0
 PART A * HTL*TJ4*FF2*2.0 (FASTENER INSTALLATION)
 F 17 7 (17*1)+(17*2)+(17*3)+(17*4)+(17*5)+(17*6) * .34 * FM1 HTL
 TOTAL ASSY LABOR HOURS * AMF1*FM1
 (BOX ASSEMBLY HORN TAIL)
 F 18 1 ((5*9)+(6*9)+(7*9)) * .10 + (15*10)
 WNG*HAS1+PART B (TRANSPORTATION + POSITIONING)
 F 18 2 (SPL VTL + KP VTL) * .210 * (8*7)
 (SPL+KP) * HTL*TJ4 (PANEL FIT + TRIM)
 F 18 3 (15*7) * 1.230
 PART A * HTL (ASSY CLAMP + LAYOUT)
 F 18 4 (15*7) * .557 * (8*7)

F 18 5 PART A *H10*TJ4 (HOLE DRILLING)
 (15,7) * .810 * (8,7) * FF1 VTL
 PART A *HE*TJ4*FF1 (FINISH OPERATIONS)
 F 18 6 (15,7) * .970 * (8,7) * FF2 VTL
 PART A *HFI*TJ4*FF2 (FASTENER INSTALLATION)
 F 18 7 (18,1)+(18,2)+(18,3)+(18,4)+(18,5)+(18,6) * .68 * FM1 VTL
 TOTAL ASSY LAFOR HOURS *AMF1*FM1
 (BOX ASSEMBLY VERT TAIL)

C FIRST UNIT COST

C

N 9

T

C STRUCTURAL BOX

F 21 1 (5,1) / (5,3) * 51.0 * (5,3)**.67
 HF1 E1
 F 21 2 (9,2) / (5,3) * 14.5 * (5,3)**.67
 HF4 E4
 F 21 3 W1 WNG**.77*RMC1 WNG*SF1 WNG + (12,3)
 F 21 4 (5,4) / (5,6) * 51.0 * (5,6)**.67
 HF1 E1
 F 21 5 (9,5) / (5,6) * 14.5 * (5,6)**.67
 HF4 E4
 F 21 6 W1 HTL**.77*RMC1 HTL*SF1 HTL + (13,3)
 F 21 7 (5,7) / (5,9) * 51.00 * (5,9)**.67
 HF1 E1
 F 21 8 (9,8) / (5,9) * 14.50 * (5,9)**.67
 HF4 E4
 F 21 9 W1 VTL**.77*RMC1 VTL*SF1 VTL + (14,3)

D RIBS

F 22 1 (6,1) / (6,3) * 52.0 * (6,3)**.67
 HF2 E2
 F 22 2 (10,2) / (6,3) * 19.0 * (6,3)**.67
 HF5 E5
 F 22 3 W4 WNG**.77*RMC4 WNG*SF4 WNG + (12,6)
 F 22 4 (6,4) / (6,6) * 52.0 * (6,6)**.67
 HF2 E2
 F 22 5 (10,5) / (6,6) * 19.0 * (6,6)**.67
 HF5 E5
 F 22 6 W4 HTL**.77*RMC4 HTL*SF4 HTL + (13,6)
 F 22 7 (6,7) / (6,9) * 52.00 * (6,9)**.67
 HF2 E2
 F 22 8 (10,8) / (6,9) * 19.00 * (6,9)**.67
 HF5 E5
 F 22 9 W4 VTL**.77*RMC4 VTL*SF4 VTL + (14,6)

D SPARS

F 23 1 (7,1) / (7,3) * 11.0 * (7,3)**.67
 HF3 E3
 F 23 2 (11,2) / (7,3) * 7.2 * (7,3)**.67
 HF6 E6
 F 23 3 W1 WNG**.77*RMC7 WNG*SF1 WNG + (12,9)
 F 23 4 (7,4) / (7,6) * 11.0 * (7,6)**.67
 HF3 E3
 F 23 5 (11,5) / (7,6) * 7.2 * (7,6)**.67
 HF6 E6
 F 23 6 W1 HTL**.77*RMC7 HTL*SF1 HTL + (13,9)
 F 23 7 (7,7) / (7,9) * 11.00 * (7,9)**.67
 HF3 E3
 F 23 8 (11,8) / (7,9) * 7.200 * (7,9)**.67
 HF6 E6
 F 23 9 W1 VTL**.77*RMC7 VTL*SF1 VTL + (14,9)

U COVERS

AF5 F5

F 35 9 WD VTL**.77 * RMC14 VTL * SF14 VTL
 D TIPS
 F 36 3 WD WNG**.77 * RMC15 WNG * SF15 WNG
 D SPOILERS
 F 37 1 CC7 WNG * 40.0 * WD7 WNG**.67
 D C7 E13
 F 37 2 CC7 WNG * 42.0 * WD7 WNG**.67
 D C7 F7
 F 37 3 WD7 WNG**.77 * RMC16 WNG * SF16 WNG
 D FLAPS + FLAP KNOBS
 F 38 4 CC8 HTL * 10.0 * WD8 HTL**.67
 D C8 E19
 F 38 5 CC8 HTL * 17.5 * WD8 HTL**.67
 D C8 F8
 F 38 6 WD8 HTL**.77 * RMC17 HTL * SF17 HTL
 D ATTACHMENT STRUCTURE
 F 39 4 CC9 HTL * 13.0 * WD9 HTL**.67
 D C9 F20
 F 39 5 CC9 HTL * 23.0 * WD9 HTL**.67
 D C9 F9
 F 39 6 WD9 HTL**.77 * RMC18 HTL * SF18 HTL
 D ACCESS + OTHER DOORS
 F 40 3 WD10 WNG**.77 * RMC19 WNG * SF19 WNG
 D AIR INDUCTION
 F 41 3 WD11 WNG**.77 * RMC20 WNG * SF20 WNG
 D HIGH LIFT DUCTING
 F 42 3 WD12 WNG**.77 * RMC21 WNG * SF21 WNG
 D SLATS
 F 43 4 CC13 HTL * 25.0 * WD13 HTL**.67
 D C13 E24
 F 43 5 CC13 HTL * 21.0 * WD13 HTL**.67
 D C13 F13
 F 43 6 WD13 HTL**.77 * RMC22 HTL * SF22 HTL
 D HINGES, BRACKETS, SEALS
 F 44 4 CC14 HTL * 10.0 * WD14 HTL**.67
 D C14 E25
 F 44 5 CC14 HTL * 10.0 * WD14 HTL**.67
 D C14 F14
 F 44 6 WD14 HTL**.77 * RMC23 HTL * SF23 HTL
 D PIVOTS + FOLDS
 F 45 3 WD15 WNG**.77 * RMC24 WNG * SF24 WNG
 D CENTER SECTION
 F 46 4 CC3 HTL * 67.0 * WD3 HTL**.67
 D C3 E9
 F 46 5 CC3 HTL * 67.0 * WD3 HTL**.67
 D C3 F3
 F 46 6 WD3 HTL**.77 * RMC12 HTL * SF12 HTL
 D ELEVATORS
 F 47 4 CC17 HTL * 5.5 * WD17 HTL**.67
 D C17 E28
 F 47 5 CC17 HTL * 5.5 * WD17 HTL**.67
 D C17 F17
 F 47 6 WD17 HTL**.77 * RMC26 HTL * SF26 HTL
 D BALANCE WEIGHTS
 F 48 7 CC3 VTL * 60. * WD3 VTL**.67
 D C3 E9
 F 48 8 CC3 VTL * 45. * WD3 VTL**.67
 D C3 F3
 F 48 9 WD3 VTL**.77 * RMC12 VTL * SF12 VTL
 D RUDDER

Reproduced from
best available copy.

F 49 1 CC10 WNG * 50.0 * WD16 WNG**.67
 WC10 E27
 F 49 2 CC10 WNG * 30.0 * WD16 WNG**.67
 WF10 F16
 F 49 3 WD10 WNG*.77 * KMC25 WNG * SF25 WNG
 D OTHER
 C
 F 50 1 (6,5) * FF3 WNG * 2.48 * CMB WNG
 HE
 F 50 5 (6,6) * FF3 HTL * 2.48 * CMB HTL
 HE
 F 50 8 (6,9) * FF3 VTL * 2.48 * CMB VTL
 HE
 F 51 2 (WRKP WNG+ 2.0 + 2.*FSL WNG+2.*ERL WNG+2.*RSL WNG)**.95*(50,1)
 CSO WR
 F 51 3 (51,2) * .68 * FM2 WNG
 AMF4
 F 51 5 (WRKP HTL+ 1.0 + 2.*FSL HTL+2.*ERL HTL+2.*RSL HTL)**.67*(50,5)
 CSO WR
 F 51 6 (51,5) * .68 * FM2 HTL
 AMF4
 F 51 8 (WRKP VTL + FSL VTL + FRL VTL + RSL VTL)**.95* (50,8)
 WR
 F 51 9 (51,8) * .68 * FM2 VTL
 AMF4
 (LINE 56 ASSEMBLY)
 F 52 2 AS2 WNG * .07 * 2.0
 HS
 F 52 5 AS2 HTL * .07 * 2.0
 HS
 F 52 8 AS2 VTL * .07 * 2.0
 HS
 (LINE 56 PAINT + FINISH)
 F 53 2 (51,2) * .1
 U
 F 53 5 (51,5) * .1
 U
 F 53 8 (51,8) * .1
 U
 (RETURK)
 R 55 1 9 3 19 31 1
 D SUB-TOTAL
 C
 F 56 2 ((25,1)+(25,2)+(26,2)+(55,1)+(55,2))*1 +(51,2)+(52,2)+(53,2)
 F 56 3 (51,3) * 1.0
 F 56 5 ((25,4)+(25,5)+(26,5)+(55,4)+(55,5))*1 +(51,5)+(52,5) +(53,5)
 F 56 6 (51,6) * 1.0
 F 56 8 ((25,7)+(25,8)+(26,7)+(55,7)+(55,8))*1 +(51,7)+(52,8) +(53,8)
 F 56 9 (51,9) * 1.0
 D FINAL ASSY
 P
 N 6
 1 FUSLGSUB- FUSLGNACELSUB- NACEL
 2 UFAB ASSY MATL UFAB ASSY MATL
 3 HOURS HOURS \$ HOURS HOURS \$
 T
 C
 C BASIC STRUCTURE
 C
 C SUBTOTAL
 C

F104 11 (104,1) + (104,3) + (104,5)
 F104 12 (104,2) + (104,4) + (104,6)
 D FINAL ASSEMBLY
 F105 11 (0.0 + 0.0)
 F105 12 (105,11) * 14.0
 D LABOR RATE
 D MAJOR MATE
 F106 2 (25,3) + (26,3) + (55,3) + (56,3)
 F106 4 (25,6) + (26,6) + (55,6) + (56,6)
 F106 6 (25,9) + (26,9) + (55,9) + (56,9)
 F106 12 (106,2) + (106,4) + (106,6)
 D MATERIAL
 C
 F110 11 (101,11) + (102,11) + (103,11) + (104,11) + (105,11) + (106,11)
 F110 12 (101,12) + (102,12) + (103,12) + (104,12) + (105,12) + (106,12)
 D TOTALS
 F111 1 (102,3) + (103,3) + (104,3)
 F111 2 (102,5) + (103,5) + (104,5)
 F111 3 (102,1) + (103,1) + (104,1)
 P
 N 6
 1 EXPANDING FUSE NACE SUB- DOLL
 2 RAGE LAGE LLE TOTALAR
 3 HOURSHOURSHOURSHOURSHOURSCOSTS
 C
 C
 C AEROSPACE VEHICLE STRUCTURAL COSTS
 C
 C NONRECURRING DESIGN AND DEVELOPMENT COSTS
 C
 C
 T
 C
 B (5(5X,F7.0)3X,-6PF7.4)
 F120 1 EN VTL + WAMPR VTL*.95
 AE
 F120 5 (120,1) + (120,2) + (120,3) + (120,4)
 D BASIC STRUCT DESIGN ENGR HRS
 F121 5 (120,5) * 1.15
 F1
 F121 6 (121,5) * 20.0
 ECLR
 D CONFIGURATION DESIGN ENGR HRS
 F122 6 (121,6) * .10
 F2
 D ENGINEERING MATERIAL
 F123 6 (121,6) + (122,6)
 D TOTAL TRADE STUDY ENGR
 C
 C
 C
 N 7
 1 HORIZVERT WING FUSE NAC DOL
 2 VONTALICAL LAGE ELLE SUB- LAR
 3 STAB STAB TOTALCOSTS
 C
 T
 C
 B (5(5X,F7.0)3X,-6PF7.4)

F130 2 TMF VTL + TAMPR VTL**1.0
 C
 F130 6 (130,1) + (130,2) + (130,3) + (130,4) + (130,5)
 D BASIC TOOL MFG HOURS
 F131 6 (130,6) * (16.0**.20 -1.)
 T B
 D RATE TOOLING MFG HOURS
 F132 6 (130,6) * 16.0**.20
 T B
 F132 7 (132,6) * 15.6
 THC
 D TOTAL TOOL MFG HOURS
 F133 6 (130,6) * .40
 F3
 D BASIC TOOL ENGRG HOURS
 F134 6 (131,6) * .20
 F4
 D RATE TOOL ENGRG HOURS
 F135 6 (133,6) + (134,6)
 F135 7 (135,6) * 17.92
 TEC
 D TOTAL TOOL ENGRG HOURS
 F136 6 (132,6) * .02
 F5
 F136 7 (136,6) * 14.30
 TDC
 D MFG DEVEL + PLANT ENGR HRS
 F137 7 (132,6) * 1.0
 F6
 D TOOLING MALT + OTHER DOLLARS
 F138 7 (121,6) * .10
 F7
 D MANUFACTURING SUPPORT DOLLARS
 F139 6 (121,5) * .01 + (132,6) * .06
 F8 F9
 F139 7 (139,6) * 14.50
 RGC
 D QUALITY CONTROL HOURS
 P
 C
 C AEROSPACE VEHICLE STRUCTURAL COSTS
 C
 C RECURRING AIRFRAME PRODUCTION COSTS
 C
 C
 N 7
 1 HORIZVERT WING FUSE NAC
 2 STAB STAB LAGE ELLE HOURS \$
 T
 C KUT+E (18)
 C
 C
 F140 6 (121,5) + ((18.0)**.20 -1.0)
 N1 ES
 F140 7 (140,6) * 20.0
 ECLR
 D SUSTAINING ENGRG
 F141 6 ((102,6) + (135,6) + (136,6)) * (18.0**.14 - 1.0)
 N1 IU
 F141 7 (141,6) * 16.40
 KT

D SUSTAINING TOOLING
 C MANUFACTURING
 C
 Z142 2 24 101 5 18. .74
 N1 PC1
 F142 6 (142,1)+(142,2)+(142,3)+(142,4)+(142,5)
 F142 7 (142,6) * 14.0
 LABOR RATE
 D DETAIL FAB HOURS
 Z143 2 24 111 2 18. .81
 N1 PC2
 F143 6 (143,1)+(143,2)+(143,3)+(143,4)+(143,5)
 F143 7 (143,6) * 14.0
 LABOR RATE
 D ASSEMBLY HOURS
 F144 6 ((142,6)+(143,6)) * .10
 F10
 F144 7 (144,6) * 14.50
 RQC
 D QUAL QNTL HOURS
 Z145 2 24 100 6 18. .93
 N1 PC3
 F145 7 (145,1)+(145,2)+(145,3)+(145,4)+(145,5)
 D MATERIAL + OTHER
 F140 1 (132,6) + (135,6) + (136,6)
 C
 C
 C PROCUREMENT ARTICLES (408)
 C
 C
 F150 6 (121,5) * (506,**.20 - 18.**.20)
 N2 ES N1 ES
 F150 7 (150,6) * 20.0
 ECLR
 D SUSTAINING ENGRG
 F151 6 (140,1) * (506,**.14 - 18.**.14)
 N2 TU N1 TU
 F151 7 (151,6) * 16.40
 RT
 D SUSTAINING TOOLING
 C MANUFACTURING
 C
 Z152 2 29 101 5 18. 506. .74
 N1 N2 PC1
 F152 6 (152,1)+(152,2)+(152,3)+(152,4)+(152,5)
 F152 7 (152,6) * 14.0
 LABOR RATE
 D DETAIL FAB HOURS
 B (5(3X,F7.0)3X,-6PF7.4,3X,-6PF7.3)
 Z153 2 29 111 2 18. 506. .81
 N1 N2 PC2
 F153 6 (153,1)+(153,2)+(153,3)+(153,4)+(153,5)
 F153 7 (153,6) * 14.0
 LABOR RATE
 D ASSEMBLY HOURS
 B (5(3X,F7.0)3X,-6PF7.4)
 F154 6 ((152,6)+(153,6)) * .10
 F11
 F154 7 (154,6) * 14.50
 RQC
 D QUAL QNTL HOURS

B (7(5X,-0PF7.4))
Z155 2 29 100 6 18. 506. .93
N1 N2 PC3
F155 7 (155,1)+(155,2)+(155,3)+(155,4)+(155,5)
D MATERIAL + OTHER
L
E
R
>

APPENDIX B
SAV MATRIX EXAMPLE

123	0.	0.	0.	5.35E+06	0.	0.
136	0.	0.	0.	1.14E+06	0.	0.
131	0.	0.	0.	8.44E+05	0.	0.
132	0.	0.	0.	1.98E+06	3.09E+07	0.
133	0.	0.	0.	4.55E+05	0.	0.
134	0.	0.	0.	1.69E+05	0.	0.
135	0.	0.	0.	6.24E+05	1.12E+07	0.
136	0.	0.	0.	3.96E+04	5.67E+05	0.
137	0.	0.	0.	0.	1.98E+06	0.
138	0.	0.	0.	0.	4.66E+05	0.
139	0.	0.	0.	1.21E+05	1.76E+06	0.
140	0.	0.	0.	1.94E+05	3.81E+06	0.
141	0.	0.	0.	1.32E+06	2.16E+07	0.
142	0.	0.	0.	1.95E+05	2.73E+06	0.
143	0.	0.	0.	5.68E+05	7.95E+06	0.
144	0.	0.	0.	7.63E+04	1.11E+06	0.
145	0.	0.	0.	0.	1.54E+06	0.
146	2.65E+06	0.	0.	0.	0.	0.
150	0.	0.	0.	4.15E+05	6.22E+06	0.
151	0.	0.	0.	2.35E+06	3.97E+07	0.
152	0.	0.	0.	1.25E+06	1.75E+07	0.
153	0.	0.	0.	0.	0.	0.
154	0.	0.	0.	1.25E+05	1.61E+06	0.
155	0.	0.	0.	0.	0.	0.

APPENDIX C
CONVERSIONS TO COMPUTER PROGRAM SYMOLOGY
NAMELIST VARIABLES

Input Source Code

APAS Program	-	A
Secondary Structure Synthesis	-	S
Complexity Factor Tables	-	C
Other	-	O

FIRST UNIT COST

(Use on WING, HSTAB, VSTAB)

		<u>INPUT SOURCE</u>
BOX DETAIL FABRICATION		
W1	Weight of ribs	A
W2	Weight of ribs	"
W3	Weight of ribs	"
WT	Total weight of W1, W2, W3	"
W4	Weight of spars	"
W5	Weight of spars	"
W6	Weight of spars	"
WT1	Total weight of W4, W5, W6	"
W7	Weight of covers	"
W8	Weight of covers	"
W9	Weight of covers	"
WT2	Total weight of W7, W8, W9	"
CF1	Complexity factor — ribs	C
CF2	Complexity factor — ribs	"
CF3	Complexity factor — ribs	"
CF4	Complexity factor — spars	"
CF5	Complexity factor — spars	"
CF6	Complexity factor — spars	"
CF7	Complexity factor — covers	"
CF8	Complexity factor — covers	"
CF9	Complexity factor — covers	"
Subassembly		
CM1	Complexity factor — ribs	"
CM2	Complexity factor — ribs	"
CM3	Complexity factor — ribs	"
CM4	Complexity factor — spars	"
CM5	Complexity factor — spars	"
CM6	Complexity factor — spars	"
CM7	Complexity factor — covers	"
CM8	Complexity factor — covers	"
CM9	Complexity factor — covers	"
Primary Box Assembly		
CN	Number of cover panels	A
RN	Number of ribs	"
SNE	Number of external spars	"

SNI	Number of internal spars	A
SPE	Average spar perimeter in feet	"
RP	Average rib perimeter in feet	"
TJ4	Joint thickness ratio	"
TS4	Average skin thickness	"
FF1	Factor for fastener selection	O
FF2	Factor for fastener selection	O

Secondary Structure

CB1	Complexity factor — leading edge	C
WD1	Weight — leading edge	S
CC1	Complexity factor — leading edge	C
CB2	Complexity factor — trailing edge	C
WD2	Weight — trailing edge	S
CC2	Complexity factor — trailing edge	C
CB3	Complexity factor — aileron, elevator, rudder	C
WD3	Weight — aileron, elevator, rudder	S
CC3	Complexity factor — aileron, elevator, rudder	C
CB4	Complexity factor — fairings	C
WD4	Weight — fairings	S
CC4	Complexity factor — fairings	C
CB5	Complexity factor — tips	C
WD5	Weight — tips	S
CC5	Complexity factor — tips	C
CB6	Complexity factor — spoilers	C
WD6	Weight — spoilers	S
CC6	Complexity factor — spoilers	C
CB7	Complexity factor — flaps	C
WD7	Weight — flaps	S
CC7	Complexity factor — flaps	C
CB8	Complexity factor — attachment struct.	C
WD8	Weight — attachment structure	S
CC8	Complexity factor — attachment struct.	C
CB9	Complexity factor — access doors, etc.	C
WD9	Weight — access doors, etc.	S
CC9	Complexity factor — access doors, etc.	C
CB10	Complexity factor — air induction	C
WD10	Weight — air induction	S
CC10	Complexity factor — air induction	C
CB11	Complexity factor — high lift ducting	C
WD11	Weight — high lift ducting	S
CC11	Complexity factor — high lift ducting	C
CB12	Complexity factor — slats	C
WD12	Weight — slats	S
CC12	Complexity factor — slats	C

CB13	Complexity factor — hinges, etc.	C
WD13	Weight — hinges, etc.	S
CC13	Complexity factor — hinges, etc.	C
CB14	Complexity factor — pivots and folds	C
WD14	Weight — pivots and folds	S
CC14	Complexity factor — pivots and folds	C
CB15	Complexity factor — center section	C
WD15	Weight — center section	S
CC15	Complexity factor — center section	C
CB16	Complexity factor — other	C
WD16	Weight — other	S
CC16	Complexity factor — other	C
CB17	Complexity factor — balance weight	C
WD17	Weight — balance weight	S
CC17	Complexity factor — balance weight	C

Final Assembly

WRRP	Root rib length	A
CSO	Center section operator	O
FSL	Front spar length	A
ERL	End rib length	A
RSL	Rear spar length	A
TJ7	Joint thickness ratio	A
TS7	Average skin thickness	A
FF3	Factor for fastener selection	O
CMB	Complexity factor	C
AS2	Surface area — ft. ²	A

Primary Box — Material Cost

RMC1	Raw material cost — ribs	O
SF1	Scrapage factor — ribs	"
RMC2	Raw material cost — ribs	"
SF2	Scrapage factor — ribs	"
RMC3	Raw material cost — ribs	"
SF3	Scrapage factor — ribs	"
RMC4	Raw material cost — spars	"
SF4	Scrapage factor — spars	"
RMC5	Raw material cost — spars	"
SF5	Scrapage factor — spars	"
RMC6	Raw material cost — spars	"
SF6	Scrapage factor — spars	"
RMC7	Raw material cost — covers	"
SF7	Scrapage factor — covers	"
RMC8	Raw material cost — covers	"
SF8	Scrapage factor — covers	"

RMC9	Raw material cost -- covers	(
SF9	Scrapage factor -- covers	"

Secondary Structure Material Cost

RMC10	Raw material cost -- leading edge	"
SF10	Scrapage factor -- leading edge	"
RMC11	Raw material cost -- trailing edge	"
SF11	Scrapage factor -- trailing edge	"
RMC12	Raw material cost -- aileron, elevator, rudder	"
SF12	Scrapage factor -- aileron, elevator, rudder	"
RMC13	Raw material cost- fairings	"
SF13	Scrapage factor -- fairings	"
RMC14	Raw material cost -- tips	"
SF14	Scrapage factor -- tips	"
RMC15	Raw material cost -- spoilers	"
SF15	Scrapage factor -- spoilers	"
RMC16	Raw material cost -- flaps	"
SF16	Scrapage factor -- flaps	"
RMC17	Raw material cost -- attachment structure	"
SF17	Scrapage factor -- attachment structure	"
RMC18	Raw material cost -- access doors, etc.	"
SF18	Scrapage factor -- access doors, etc.	"
RMC19	Raw material cost -- air induction	"
SF19	Scrapage factor -- air induction	"
RMC20	Raw material cost -- high lift ducting	"
SF20	Scrapage factor -- high lift ducting	"
RM21	Raw material cost -- slats	"
SF21	Scrapage factor -- slats	"
RMC22	Raw material cost -- hinges, etc.	"
SF22	Scrapage factor -- hinges, etc.	"
RMC23	Raw material cost -- pivots and folds	"
SF23	Scrapage factor -- pivots and folds	"
RMC24	Raw material cost -- center section	"
SF24	Scrapage factor -- center section	"
RMC25	Raw material cost -- other	"
SF25	Scrapage factor -- other	"
RMC26	Raw material cost -- balance weight	"
SF26	Scrapage factor -- balance weight	"

Primary Box Assembly Material Cost

FM1	Complexity factor -- fastener type	"
-----	------------------------------------	---

Assembly Material Cost

FM2	Complexity factor -- fastener type	"
-----	------------------------------------	---

NONRECURRING DESIGN AND DEVELOPMENT COSTS

		<u>INPUT SOURCE</u>
EH	Engineering Hours at WAMPR + 1 Pound	O
WAMPR	Weight of the Structure Element	A
TMF	Tooling complexity Factor by Component	O
TAMPR	Weight in Pounds by Component	A

APPENDIX D
CONVERSION TO COMPUTER PROGRAM SYMBOLOGY -
ESTIMATING COEFFICIENTS

Input Source Code

Coefficient Derivation	-	D
Other	-	O

FIRST UNIT COST

(Use - WING, HSTAB, VSTAB)

Box Detail Fabrication

		INPUT SOURCE
HF1	Fabrication hours — ribs	D
E1	Exponent — ribs	"
HF2	Fabrication hours — spars	"
E2	Exponent — spars	"
HF3	Fabrication hours — covers	"
E3	Exponent — covers	"

Subassembly

HF4	Subassembly hours — ribs	"
E4	Exponent — ribs	"
HF5	Subassembly hours — spars	"
E5	Exponent — spars	"
HF6	Subassembly hours — covers	"
E6	Exponent — covers	"

Primary Box Assembly

HSA1	Assembly hours per unit weight	O
HSA2	Assembly hours per subassembly	"
Q	Quantity scaling factor	"
HT	Hours per lineal foot	"
HLL	Assembly hours per unit length	"
R	Size scaling exponent	"
HD	Drilling hours per foot	"
HE	Finish hours, per unit length	"
HFI	Installation hours per foot	"

Secondary Structure

WC1	Hours per pound — leading edge	D
E7	Exponent — leading edge	"
WF1	Hours per pound — leading edge	"
F1	Exponent — leading edge	"
WC2	Hours per pound — trailing edge	"
E8	Exponent — trailing edge	"
WF2	Hours per pound — trailing edge	"
F2	Exponent — trailing edge	"
WC3	Hours per pound — aileron, elevator, rudder	"
E9	Exponent — aileron, elevator, rudder	"
WF3	Hours per pound — aileron, elevator, rudder	"
F3	Exponent — aileron, elevator, rudder	"
WC4	Hours per pound — fairings	"
E10	Exponent — fairings	"

WF4	Hours per pound — fairings	D
F4	Exponent — fairings	"
WC5	Hours per pound — tips	"
E11	Exponent — tips	"
WF5	Hours per pound — tips	"
F5	Exponent — tips	"
WC6	Hours per pound — spoiler	"
E12	Exponent — spoiler	"
WF6	Hours per pound — spoiler	"
F6	Exponent — spoiler	"
WC7	Hours per pound — flaps	"
E13	Exponent — flaps	"
WF7	Hours per pound — flaps	"
F7	Exponent — flaps	"
WC8	Hours per pound — attachment structure	"
E19	Exponent — attachment structure	"
WF8	Hours per pound — attachment structure	"
F8	Exponent — attachment structure	"
WC9	Hours per pound — access doors, etc.	"
E20	Exponent — access doors, etc.	"
WF9	Hours per pound — access doors, etc.	"
F9	Exponent — access doors, etc.	"
WC10	Hours per pound — air induction	"
E21	Exponent — air induction	"
WF10	Hours per pound — air induction	"
F10	Exponent — air induction	"
WC11	Hours per pound — high lift ducting	"
E22	Exponent — high lift ducting	"
WF11	Hours per pound — high lift ducting	"
F11	Exponent — high lift ducting	"
WC12	Hours per pound — slats	"
E23	Exponent — slats	"
WF12	Hours per pound — slats	"
F12	Exponent — slats	"
WC13	Hours per pound — hinges, etc.	"
E24	Exponent — hinges, etc.	"
WF13	Hours per pound — hinges, etc.	"
F13	Exponent — hinges, etc.	"
WC14	Hours per pound — pivots and folds	"
E25	Exponent — pivots and folds	"
WF14	Hours per pound — pivots and folds	"
F14	Exponent — pivots and folds	"
WC15	Hours per pound — center section	"
E26	Exponent — center section	"

WF15	Hours per pound — center section	D
F15	Exponent — center section	"
WC16	Hours per pound — other	"
E27	Exponent — other	"
WF16	Hours per pound — other	"
F16	Exponent — other	"
WC17	Hours per pound — balance weight	"
E28	Exponent — balance weight	"
WF17	Hours per pound — balance weight	"
F17	Exponent — balance weight	"

Final Assembly

R1	Size scaling parameters	O
HE1	Cost per unit length for assembly	"
HS	Hours per square foot factor	"
U	Rework factor	"

Primary Box Assembly Material Cost

AMF1	Assembly material per labor hour	"
------	----------------------------------	---

Assembly Material Cost

AMF4	Assembly material per labor hours	"
------	-----------------------------------	---

NONRECURRING DESIGN AND DEVELOPMENT COSTS

(Use - WING, HSTAB, VSTAB)

INPUT
SOURCE

Basic Structure Design Engineering Hours

AE	Exponent - Hours to AMPR Weight	O
----	---------------------------------	---

Configuration Design Engineering Hours

F1	Factor - Applied to Total Engineering Hrs.	"
ECLR	Engineering Composite Labor Rate	"

Engineering Material

F2	Factor - % of Engineering Labor Cost	"
----	--------------------------------------	---

Basic Tool Manufacturing Hours

C	Exponent - Hours by AMPR Weight	"
---	---------------------------------	---

Rate Tooling Manufacturing Hours		
T	Assumed Monthly Production Rate	"
B	Exponent - Tool Production Rate	"
Total Tool Manufacturing Hours		
THC	Labor Cost Per Hour	"
Basic Tool Engineering Hours		
F3	Factor - % of Basic Tool Manufacturing Hours	"
Rate Tool Engineering Hours		
F4	Factor - % of Rate Tool Engineering Hours	"
Total Tool Engineering Hours		
TEC	Labor Cost Per Hour	"
Manufacturing Development and Plant Engineering Hours		
F5	Factor - % of Mfg. Devel. and Plant Engrg. Hours	"
TDC	Composite Labor Cost	"
Tooling Material and Other Costs		
F6	Factor - Tooling Material Support (\$/Hr.)	0
Manufacturing Support Dollars		
F7	Factor - Development Support (\$/Hr.)	"
Quality Control Hours		
F8	Factor - % of Engineering Direct Labor Hours	"
F9	Factor - % of Tool Mfg. Direct Labor Hours	"
RQC	Composite Labor Rate	"

RECURRING AIRFRAME PRODUCTION COSTS (RDT&E ARTICLES)

Sustaining Engineering		
N1	Number of RDT&E Airframes	"
ES	Exponent - Sustaining Engrg. with Quantity	"

Sustaining Tooling

TU	Exponent - Sustaining Tooling with Quantity	"
RT	Composite Tooling Labor Rate	"

MANUFACTURING

DETAIL FABRICATION HOURS

PC1	Learning Curve Decimal Fraction	"
RM	Manufacturing Labor Rate	"

Assembly Hours

PC2	Learning Curve Decimal Fraction	"
-----	---------------------------------	---

Quality Control Hours

F10	Factor - Ratio Between Quality Control and Mfg. Hours	"
-----	--	---

Material and Others

PC3	Learning Curve Decimal Fraction	"
-----	---------------------------------	---

RECURRING AIRFRAME PRODUCTION COSTS (PROCUREMENT ARTICLES)

Sustaining Engineering

N2	Sum of RDT&E and Procurement Production Quantities	"
----	---	---

Manufacturing

Quality Control Hours

F11	Factor - Ratio Between Quality Control and Mfg. Hr. for Procurement Production	"
-----	--	---

APPENDIX E
COMPLEXITY FACTOR TABLES

Table I. Complexity Factors, Rib Detail Fabrication.

Structural Element CER Input Symbol	Material Type	Construction Type				
		Built-Up Web Stiffener	Build-Up Truss	Sheet Web	Corrugated Web	Integral Web Stiffener
Ribs, Detail Fabrication CF ₁	Aluminum	1.00	.70	.52	.51	.59
	Titanium	1.31	.95	.59	.57	1.82
	Low Carbon Steel	1.05	.77	.54	.53	1.21
	Stainless Steel	1.56	1.15	.64	.62	2.48
						2.54

Table II. Complexity Factors, Rib Subassembly

Structural Element CER Input Symbol	Material Type	Construction Type			
		Built-Up Web Stiffener	Build-Up Truss	Sheet Web	Corrugated Web
Ribs, Subassembly CM ₁	Aluminum	1.00	.89	0	.2.08
	Titanium	1.75	1.57	0	2.58
	Low Carbon Steel	1.19	1.07	0	2.22
	Stainless Steel	2.33	2.10	0	2.98

Table III Complexity Factors, Spar Detail Fabrication.

Structural Element CER Input Symbol	Material Type	Construction Type				
		Built-Up Web Stiffener	Build-Up Truss	Sheet Web	Corrugated Web	Integral Web Stiffener
Spars, Detail Fabrication CERF ₁	Aluminum	1.00	.83	.68	.64	1.72
	Titanium	1.21	1.05	.68	.67	3.22
	Low Carbon Steel	1.05	.88	.68	.65	2.12
	Stainless Steel	1.34	1.22	.68	.70	4.42
						5.20

Table IV. Complexity Factors, Spar Subassembly.

Structural Element CER Input Symbol	Material Type	Construction Type				
		Built-Up Web Stiffener	Build-Up Truss	Sheet Web	Corrugated Web	Integral Web Stiffener
Spars, Subassembly CM _i	Aluminum	1.00	1.20	0	3.84	0
	Titanium	1.72	1.52	0	5.40	0
	Low Carbon Steel	1.20	1.28	0	4.22	0
	Stainless Steel	2.31	1.77	0	6.75	0

Table V. Complexity Factors, Cover Detail Fabrication.

Structural Element CER Input Symbol	Material Type	Construction Type		
		Built-Up Skin Stringer	Integral Skin Stringer	Machined Plate Sheet
Covers, Detail Fabrication	Aluminum	1.00	2.72	2.40 .75
	Titanium	1.10	5.20	4.50 .80
	Low Carbon Steel	1.03	3.38	2.97 .76
	Stainless Steel	1.19	7.22	6.23 .84

Table VI. Complexity Factors, Cover Subassembly.

Structural Element CER Input Symbol	Material Type	Construction Type		
		Built-Up Skin Stringer	Integral Skin Stringer	Machined Plate
Covers, Subassembly	Aluminum	1.00	0 1.0	0 1.0 0 1.0
	Titanium	2.24	0 1.0	0 1.0 0 1.0
	Low Carbon Steel	1.33	0 1.0	0 1.0 0 1.0
	Stainless Steel	3.22	0 1.0	0 1.0 0 1.0

APPENDIX F
LOOK-UP TABLES

Table VII. Engineering CER Coefficients.

COEFFICIENT	FIGHTERS			TRANSPORTS		
	Empennage	Wing	Fuselage	Empennage	Wing	Fuselage
b, scaling exponent	0.95	0.82	0.98	0.95	0.82	0.98
a, intercept at weight = 1 lb	60	126	63	60	77	33

Table VIII. Tool Manufacturing Hours Input Table.

CER Variable	Simplified Design and Follow-on Subsonic	Regular Subsonic	Complex Subsonic	Simplified Design and Follow-on Supersonic	Regular Supersonic	Complex Supersonic
Input Value (CMIT)	32.0	47.0	70.0	100.0	133.0	185.0
Scaling Exponent (C)	1.0	1.0	1.0	1.0	1.0	1.0

REFERENCES

1. G. S. Levenson, et al., "Cost-Estimating Relationships for Aircraft Airframe," The Rand Corporation, R-761-PR (abridged), February 1972.